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TASK ANALYSIS METHODS APPLICABLE TO CONTROL ROOM DESIGN REVIEW (CDR)

by

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Research report

TASK ANALYSIS METHODS APPLICABLE TO CONTROL ROOM DESIGN REVIEW

ABSTRACT

This report presents the results of a research study conducted in support of the human factors engineering program of the Atomic Energy Control Board in Canada. The overall objectives of the study were the following: to review the historical development and current status of task analysis methods applicable to complex human-machine systems design and evaluation, to develop a task analysis method applicable to CANDU nuclear plant control room design reviews, and to recommend a set of criteria for regulatory assessment of task analyses prepared by CANDU nuclear plant operators for control room design reviews and other uses, such as development of performance-related training objectives.

Task analysis is a systematic method for identifying, analyzing, and documenting the behaviour required of one or more operators for the safe and effective operation of a human-machine system under a variety of normal and abnormal operating conditions.

This document contains five products which may be used by the Atomic Energy Control Board in relation to Task Analysis of jobs in CANDU nuclear power plants:

1. a detailed method for preparing for a task analysis;
2. a Task Data Form for recording task analysis data;
3. a detailed method for carrying out task analyses;
4. a guide to assessing alternative methods for performing task analyses, if such are proposed by utilities or consultants; and
5. an annotated bibliography on task analysis.

In addition, a short explanation of the origins, nature and uses of task analysis is provided, with some examples of its cost effectiveness.

There is no substitute for Task Analysis. Where humans are involved in a system, it is of as fundamental importance as the chemistry of zirconium, the properties of concrete, and the kinetics of nuclear reactions in ensuring safe and productive operation of nuclear power plants. Like other branches of engineering, it requires trained specialists to perform it.

Task Analysis is costly and resource intensive, but the cost is reduced if it is incorporated as a component of the overall systems design at an early stage. At any time, its use can be very cost effective.

Task Analysis can be used for the following purposes among others: control room design, control room design revision, operating procedure development and evaluation, personnel selection, development of training systems, development of management policy, human risk assessment in PRA, development and assessment of maintenance practices, and design for maintenance.

The method proposed is adequate for conventional and advanced control rooms, and for behavioural and cognitive actions.

Several areas of research are strongly recommended and discussed in the report. These are derived from task analysis considerations and include:

1. the effect of "advanced" control room design and procedures on operator error;

2. the development of a standard vocabulary for describing operator actions in "advanced" control rooms with supervisory control of automatic systems; and

3. design of a data base management system to enhance the cost effectiveness of a task analysis program.

RÉSUMÉ

Le présent rapport fournit les résultats d'un projet de recherche à l'appui du programme d'ergonomie de la Commission de contrôle de l'énergie atomique au Canada. Les buts généraux du projet étaient les suivants : examiner l'évolution et l'état actuel des méthodes d'analyse des tâches applicables à la conception et à l'évaluation des systèmes hommes-machines complexes, mettre au point une méthode d'analyse des tâches applicable aux vérifications de la conception des salles de commande des centrales nucléaires CANDU et recommander une série de critères pour l'évaluation réglementaire des analyses de tâches rédigées par les opérateurs de centrales nucléaires CANDU pour les vérifications de la conception des salles de commande et pour d'autres usages, comme la mise au point d'objectifs de formation liés au rendement.

L'analyse des tâches est une méthode systématique pour préciser, analyser et documenter le comportement requis de la part d'un ou de plusieurs opérateurs en vue de l'exploitation sûre et efficace d'un système hommes-machines, dans diverses conditions d'exploitation normales et anormales.

Le présent document contient cinq éléments que la Commission de contrôle de l'énergie atomique peut utiliser par rapport aux analyses de tâches dans les centrales nucléaires CANDU :

1. une méthode détaillée pour se préparer à une analyse de tâches;

2. un formulaire de données sur les tâches pour enregistrer les données des analyses de tâches;

3. une méthode détaillée pour effectuer les analyses de tâches;

4. un guide pour évaluer d'autres méthodes pour effectuer les analyses de tâches, si de telles méthodes sont proposées par les services publics ou des consultants;

5. une bibliographie annotée sur les analyses de tâches.

En outre, le document fournit une brève explication des origines, de la nature et des utilisations possibles des analyses de tâches, ainsi que certains exemples de leur rentabilité.

Il n'existe aucun substitut à l'analyse de tâches. Si des manoeuvres humaines font partie d'un système, l'analyse de tâches est aussi importante que les propriétés chimiques du zirconium, les caractéristiques du béton et les éléments cinétiques des réactions nucléaires pour garantir l'exploitation sûre et productive des centrales nucléaires. Comme dans le cas de d'autres secteurs de l'ingénierie, il faut des spécialistes bien formés pour effectuer l'analyse de tâches.

L'analyse de tâches est coûteuse et exige beaucoup de ressources, mais le coût en est réduit si l'analyse est intégrée à la conception générale des systèmes dès le départ. Son utilisation peut être très rentable à n'importe quel stade.

L'analyse de tâches peut être utilisée à diverses fins, comme la conception des salles de commande, la vérification de la conception des salles de commande, la mise au point et l'évaluation des procédures d'exploitation, la dotation en personnel, la mise au point de programmes de formation, l'élaboration de politiques de gestion, l'évaluation des risques pour les êtres humains, l'établissement et l'évaluation de pratiques de maintenance, la conception de la maintenance, etc.

La méthode proposée convient aux salles de commande classiques et perfectionnées, ainsi qu'aux manoeuvres qui tiennent du comportement et du jugement.

Le rapport recommande fortement d'approfondir la recherche dans certains domaines qui découlent des considérations sur l'analyse de tâches et qui comprennent :

1. l'effet de la conception des salles de commande perfectionnées et des procédures qui y sont utilisées en cas d'erreur des opérateurs;

2. la mise au point d'un vocabulaire normalisé pour rendre compte des manoeuvres effectuées par les cpérateurs dans les salles de commande perfectionnées où ils ne font que surveiller les systèmes automatiques;

3. la conception d'un système de gestion des données pour améliorer la rentabilité du programme d'analyse de tâches.

DISCLAIMER

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1.0 INTRODUCTION

1.1 Definition of Task Analysis

Task analysis is a systematic method for identifying, analyzing and documenting the behaviour required of one or more operators for the safe and effective operation of a humanmachine system under a variety of operating conditions.

There is no substitute for task analysis. It is a basic building block in a systems approach to the development of complex humanmachine systems. In the design of a system, in the design of a control room, in the design of training, in the design of operating procedures, and in the design of maintenance it should be regarded as a tool of fundamental importance as fundamental as the specification of properties of materials to the civil engineer or the specification of equations describing the kinetics of the system to the nuclear or thermal engineer.

> "Task analysis is both a rational2 and empirical method. It can be used in the absence of empirical data about job performance on the basis of the following rationale: The behavioral requirements of a man-machine task are given by the equipment itself in the form of (a) the displays from which the operator must make essential discriminations, (b) various response alternatives from which decisions by the operator select a course of action, and (c) the controls which must be activated in certain ways in order that the machine will produce the criterion output intended for it within the quality tolerances specified for it. More simply stated, the way the machine is built and has to be used determines what the operator has to do. The study of the display-control characteristics of the machine into which the operator is fitted as a critical linkage or channel provides data from which behavioral requirements may be directly inferred. These inferences may remain defined by the job and task operations with a minimum of abstracting into general human traits or attributes.
>
> One assumption accepted by task analysis is that if the operational equipment is poorly designed from a human engineering standpoint, the task analysis will still be based on that equipment, poor though it may be. Task analysis may reveal that operational equipment is poorly designed for the operator, and may show why it is poorly designed. But the analysis, per se, will be a statement of the task requirements of the equipment as it stands. Should it be modified, a modified task analysis would be in order."
>
> (Miller, 1953)

This quotation is from "A Method for Man-Machine Task Analysis", in which Miller (1953) introduced the technique. The original intention of task analysis (TA) was to assist in the rational development of training. Often training methods reflected merely the intentions of the trainer or his managers plus a liberal amount of tradition. TA offered a way of discovering in great detail exactly what the operator was actually required to do. Once this was known, the way was open to train that behaviour and only that behaviour, often with very substantial financial savings.

But as Miller points out, if TA is applied to a system as given, it may reveal shortcomings in the design of that equipment. Engineers seldom are required to take courses in human factors or ergonomics as part of their training, and as a result usually do not take systematic steps to design machinery in a way which takes account of the properties of the human user. Often it is said that ergonomics is merely "common sense". But if that is so, common sense is in such remarkably short supply that it is incapable of guiding good design, as the following pictures, published after a human factors audit by the Electrical Power Research Institute of U.S. Nuclear Power Plants, (NPPs) reveal. (See Figure 1.1.F1) It should be added that while the design of NPPs in the United States provides a particularly rich source of examples of inadequate use of human factors and ergonomic data, no country at this time has such a high standard of design as to be able to feel confident that a human factors audit would not reveal such examples.

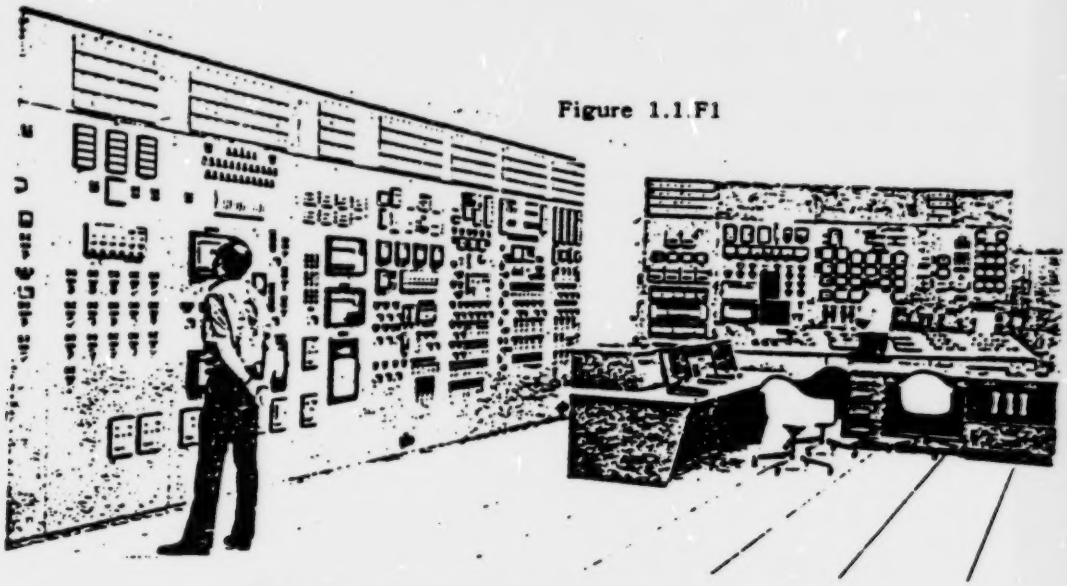
The "system as given" to use Miller's phrase includes not merely the hardware as built, but the procedures as written and the operators' skills as learned or acquired. Hence arise the claims of TA to reveal the implications of the entire human-procedures-hardware interaction for the successful control of the plant. It does not matter whether the system is simple or complex, manual or automatic. Without a TA one cannot be sure that one knows in detail whether a human can carry out his or her role safely and effectively.

It is for that reason that the U.S. Nuclear Regulatory Commission (NRC) called for task analysis as part of the Detailed Control Room Design Review (DCRDR) specified in NUREG-0700. And it is for that reason that the Atomic Energy Control Board (the AECB) should select a preferred method of task analysis and understand how to evaluate alternatives.

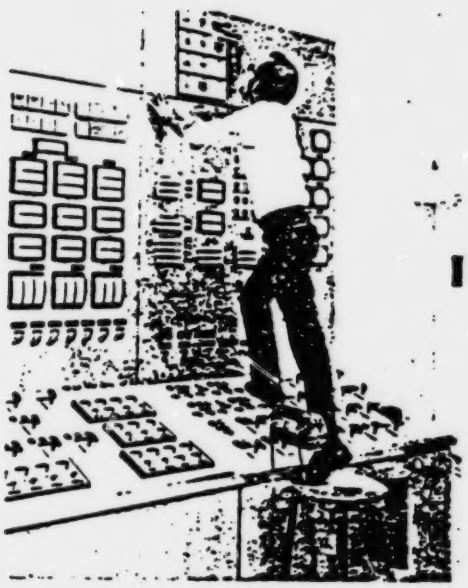
In regard to control room design TA should ideally be used at an early stage in the design of a plant. As the system design engineers develop the specifications of the plant, the nature of the tasks to be performed by operators will begin to appear, and procedures to be written. If at this stage human factors specialists are present in the design team, TAs can be performed as the design develops. The TA may show that a particular task may require the operator to activate two controls in quick succession. The blueprints or full scale mockup of the control room may reveal that they are so far apart that they cannot be operated rapidly enough. At this stage it is still cheap to redesign the control panel. But a second TA may show that the proposed alternate layout renders some other task impossible. The discussion will then lead to an understanding of inherent limitation in the system design, and in turn to discussion of operator workload and manning requirements. If it is decided that safe operation absolutely requires the rapid successive operation of controls which must, to solve simultaneously the requirements of several tasks, or for constructional reasons, be placed far apart, then more than one operator will be required for the task. This in turn will have an impact on operating procedures, and on training. It may even alter the hierarchy of command and responsibility, or (in extreme cases) management policy.

It should be clear that (1) the earlier in the design cycle TA is included the greater the cost savings; (2) that TA should play an iterative role throughout the design process and during modification throughout the life of the plant; and (3) that TA is as important in the design of "advanced" control rooms and automatic systems as in conventional and manually controlled systems.

Figure 1.1.F1



The CVCS controls are placed on the main console to the right, while most CVCS alarms are located near the man on the left.



The benchboard provides a natural foothold to replace expended lamps.

Operator sits with his back to control boards

Figure 1.1.F1

(From EPRI NP-309-SY, Human Factors Review of Nuclear Power Plant Control Room Design.)

Safe and efficient design and operation requires that a task analysis be performed in any situation where a human is to be a component in safe and efficient operation.

The role of TA in a control room design review (CRDR) is no different. Here, as Miller states, the system is "given". The hardware is in place, the procedures are in use, the operators are trained. The purpose of the TA is to establish two things:

(1) Task analysis discovers what the operator is expected to do.

(2) Task analysis discovers what the operator actually does.

If there is a discrepancy between the two, several options are available. Perhaps the training program has failed to stabilize the operator's behaviour in the desired way. In that case, no change is required in procedures or control room. Perhaps the procedures are unintelligible or ambiguous. In that case they must be rewritten. Perhaps there is a serious defect in the layout or function of displays and controls which makes it impossible or at least very difficult for the operator to carry out the procedures despite training, given the operator's physical measurements
or the limits of human information processing capacities. In that case redesign or retrofitting of the control room, introduction of new instruments, or changes in procedures or manning will be required for safe operation. It is even possible that some function which the nuclear, thermal or electrical engineer had intended to be carried out by the operator has never been written into a procedure and never appeared as a training item, and that it is only due to the rarity of the plant condition involved that the operator has never been called upon to perform the task.

The method of task analysis proposed in this document (though not the three methods already published for use in NPPs in the United States) will detect such a situation.

1.2 History of Task Analysis in Nuclear Safety

After the second world war, designers of ever more complex systems that were being developed by the military were faced with a major problem. New systems were becoming complex enough to pose severe problems for the personnel who were using them. Critical errors were occurring. Injury, loss of life, and the destruction of expensive equipment resulted from these errors. It was evident that these problems were caused by poor human-machine interfaces and inappropriate training. A method had to be developed that would help engineers determine what personnel had to do, how they did it and how they ought to do it to perform their functions. On the other side of the coin, engineers had to determine how their systems ought to be designed so that personnel trained in the use of equipment had the prerequisite skills and knowledge to handle the tasks at hand. Trainers in turn needed to know more precisely the exact skills and knowledge required. In short a method was needed to find out how a system can be designed in order to function properly using the personnel that were employed to operate it. The system had to allow the operator enough time to make decisions, to make calculations, to operate controls, to perceive information, and to communicate clearly and effectively, while avoiding situations where personnel would have too much to do. The sequencing and timing of tasks, the allocation of tasks to humans or machines, the identification of the skills and knowledge required of the operator and the interaction of tasks all had to be determined before the planning of a system was completed.

The best way to achieve such a goal is to carry out a detailed task analysis of the "human sub-system" and compare the results with the functions of the overall system. The TA can identify functions, tasks, sub-tasks or even elements of sub-tasks that must be carried out by personnel in order to reach the goals of their job. The TA can provide information needed to determine the workload tasks impose on personnel. The TA can provide information regarding the expected skills and knowledge personnel require to do the job. It can supply data necessary for human reliability analysis in plant safety analysis and to identify problems and poor practices which may increase the probability of error. Lastly, the TA can provide information necessary to pinpoint poor design features (human engineering problems) that may degrade the system.

The recognition of the problems described in the first paragraph of this section, and the use of task analysis as a means of solving them spawned a series of studies on task analysis methods useful for the design of complex systems. Miller carried out a number of such investigations during the 1950's for the USAF (Miller, 1953, 1962). The basis for his approach was the work of Taylor (1911) and Gilbreth (1911) who were pioneers in earlier methods for time and motion studies in the industrial setting. Task analysis is a direct descendent of these time and motion studies. The emphasis, however, shifted from a concern purely for efficient methods to concerns with other task attributes such as safety, comfort, workload, error reduction and human engineering as well as the effectiveness and efficiency of the tasks.

Following Miller's lead, researchers realized that a need existed for a taxonomy of terms used in describing tasks. Miller himself developed a task taxonomy to be used for task analysis (1962). Companion and Corso (1982) have reviewed and evaluated a number of task taxonomies for various applications. Berliner et al. (1964) have produced a task taxonomy that has been adopted, generally, in the nuclear power field. It is a comprehensive taxonomy of terms (vocabulary) that are appropriate to the actions (verbs) represented in most power plant control room operations (see Table 3.2.5.T3) of conventional design, (that is, those without extensive use of displays and inputs mediated by computer).

To understand task analysis in the context of nuclear plant design and operation, it is necessary to look further at the development of TA since the Three Mile Island accident in 1979. Though human factors was of some concern to designers of nuclear power plant control rooms prior to the TMI accident, it was after this event that the concern became prominent (NUREG-0660). The Nuclear Regulatory Commission (NRC) stepped up investigations into the use of human factors planning and implementation in the design of NPP control rooms. The investigations led to the integration of human factors analysis, in its fullest form, into the Control Room Design Reviews (CRDRs) that were now to be carried out in all nuclear power plant operations (NUREG-0700).

The NRC commissioned a number of research teams to develop appropriate methods for CRDR and human reliability analysis (HRA) in the control room environment, as well as in the maintenance of the plant. Von Herrmann's report (NUREG/CR-3177) for instance focussed on methods for review and evaluation of emergency procedures guidelines. Swain and Guttmann (NUREG/CR-1278) developed a handbook of human reliability analyis with emphasis on nuclear plant application. This was followed by the development of procedure for using the handbook in conducting a NPP human reliability analysis (NUREG/CR-2254). Both the handbook and the procedure are based on a human reliability model called THERP (Technique for Human Error Rate Production) developed primarily by Swain in the 1950's and 60's. The Institute of Nuclear Power Operations began work on

the development of CRDR methods which led to INPO-83-046; INPO-83-036 and INPO-83-026, with the aim of encouraging higher standards than those specified by the NRC.

The NRC and several other organizations responded to this by commissioning a number of studies to develop TA methodologies specifically for use in nuclear installations. (NUREG/CR-2598; NUREG/CR-3415; NUREG/CR-3371; INPO-83-046; DOE/EP-0095). By the mid 1980's the U.S. nuclear power industry has become generally favourable toward the use of task analysis in CRDR (see, e.g. Haeger and Stevens, 1983).

The task analysis methods currently found in the nuclear power field are a synthesis of the earlier efforts and those of later workers such as Meister (1971). The methods rely heavily on observations in training simulators using video recording for on the spot observation. Since the methods focus on what operators were actually doing, and less on what they should have been doing (for example: NUREG/CR-2598, NUREG/CR-3415, and NUREG/CR-3371), these TA's will be referred to as descriptive task analyses (See Glossary).

Some methods developed by the aerospace industry were more prescriptive (e.g. AGARD-AG-275; CAFES D180-18750-1), as were some methods described in texts (Bailey, 1982; Meister, 1971; Van Cott and Kinkade, 1972). A "prescriptive" task analysis analyzes what the operator should do rather than what he does do. The prescriptive approach has been recognized as a better way to apply task analysis to the nuclear power field by the recent study carried out by INPO (INPO-83-046 NUTAC). The INPO documents describe both prescriptive and descriptive task analyses in an overall methodology specifically developed for application to NPPs. A particular combination of methods will determine the extent of prescriptive and descriptive data that will be collected. This is a major virtue of INPO's approach. It should be noted, however, that access to INPO documents is restricted. INPO maintains rigid proprietary secrecy over their documents and appear unwilling to release them for general use.

Prescriptive data allow the analyst to first determine how the operators should act during plant operations. A subsequent descriptive analysis determines what the operators actually are.

1.3 Uses of Task Analysis

The potential uses of TA can be summarized as follows. (See also Table 1.3.T1 and 1.3.T2).

1. Control Room Design and Design Review.

It can be used early in system design to guide the design review of control rooms to minimize manning requirements while maximizing safety and productivity. In control room reviews it can reveal deficiencies and suggest remedies.

TA makes explicit all the actions which operators must perform to carry out procedures. By examining the engineering specifications, missing, imperfect or ambiguous procedures can be identified, and their adequacy or inadequacy documented. Inadequacies of several kinds may be revealed. It may be that no procedure has ever been written for a particular subsystem. It may be that the procedure exists, but is ambiguous or vague. For example, phrases such as "ensure that the pressure does not fall too rapidly" are sometimes found. Such phrases which leave it up to the subjective

interpretation of the operator as to what events satisfy the criterion "too rapidly", need to be replaced with a more exact criterion, such as "if the pressure falls by more than x kilopascals in 5 minutes". The TA can also reveal that while the procedures are clearly written the instrumentation is poor. An example would be a situation where the value of a variable which is important to the safe operation of the plant was not displayed directly, but where the operator was required to deduce the value from other variables -- such as deducing a level from pressure and temperature readings.

A TA can also reveal physical shortcomings in control room design. An operator should be able to read displays whose values are to be compared without having to walk from one part of the control room to another. An operator who operates a control should at the same time be able to read the display showing the effects of the action. The TA may reveal that a procedure requires the operator to operate two controls in quick succession which are far apart in the control room, to read a value from a digital display when the readings are changing rapidly, or at a distance at which the value is illegible. In an advanced display problems of the layout of information on the screen may be revealed, problems in keyboard layout, ambiguities in regard to which information should be displayed on which screen, or whether information already displayed will have to be over-written to display new information.

Overall, TA can guide the design of information display and control arrangements.

2. Procedures

TA can reveal inadequacies of procedures due to omissions, unintelligibility, or ambiguity. It can reveal situations in which procedures, while technically correct and sufficient to ensure safety and efficiency if carried out correctly, are too demanding on the operators in view of human limit.

3. Maintenance

Early in system design TA can indicate areas of difficulty due to inadequate access, bulky clothing, inadequate or hazardous environmental factors such as heating, lighting, exposure to radiation, etc. Changes in layout or practice can be made at a time when the cost is minimal.

4. Training and Certification

By identifying exactly the actions required, training can be rendered more efficient and shortened. Personnel selection can be justified and supported. Certification procedures, whether written or in a simulator, can be justified and supported using TA data.

5. Manning Levels

Manning levels, workload estimates, etc. can be rationally determined.

6. Supervision & Management Policy

Knowing in detail and exactly what is required of operators can aid decisions with regard to the allocation of responsibility, chains of command, and overall management policy.

JOB AND TASK ANALYSIS DATA	APPLICATIONS FOR JOB AND TASK ANALYSIS DATA																		
	TRAINING PROGRAM DEVELOPMENT AND EVALUATION								PERSONNEL MANAGEMENT	OPERATING PROCEDURES DEVELOPMENT		SYSTEM DESIGN			COMMUNICATIONS	RISK ASSESSMENT/ HUMAN PERFORMANCE PREDICTIONS		
	•		•			•		•	•					•		•		
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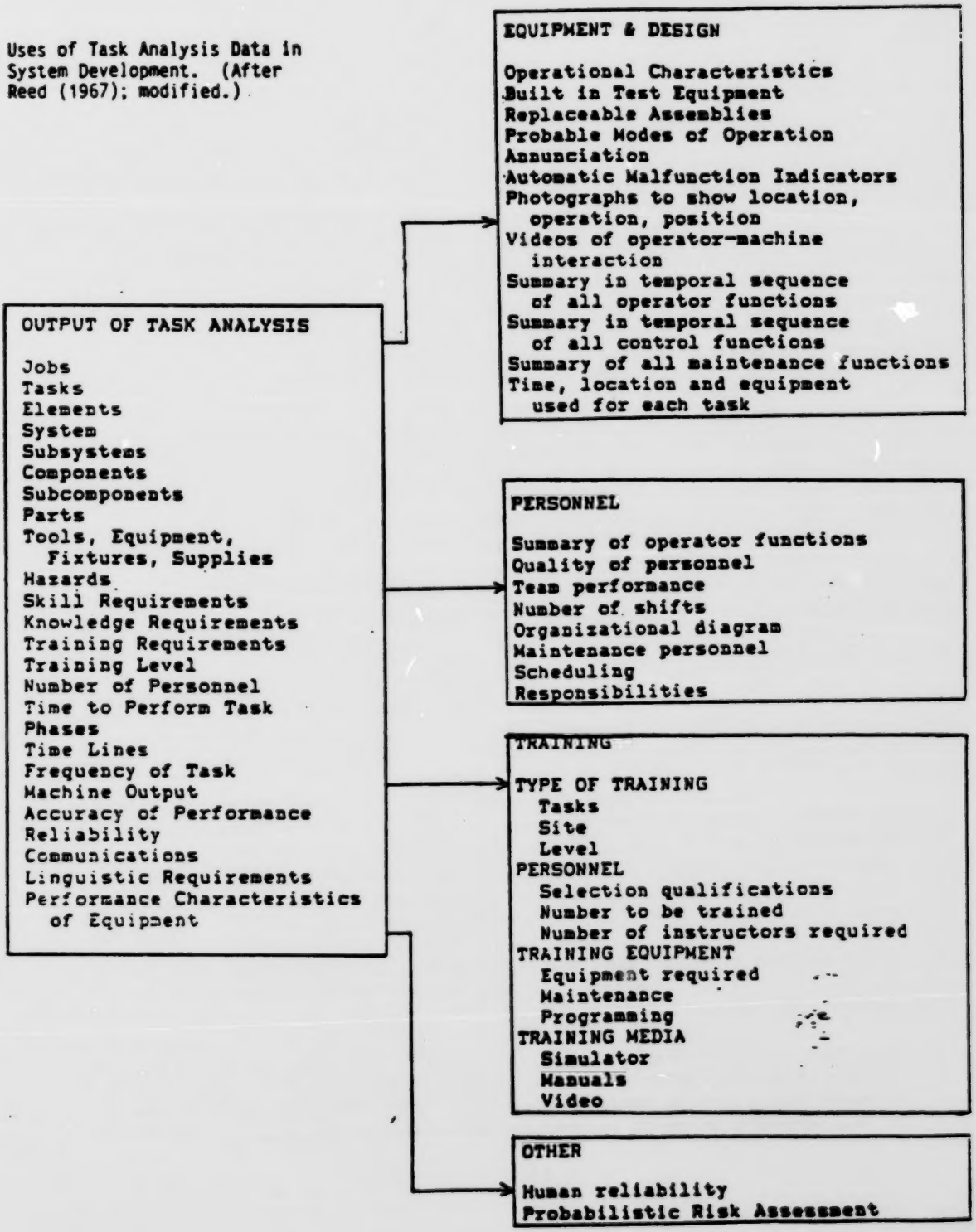
Table 1.3.T1

Uses of Task Analysis
(From NUREG/CR-0095)

1.3.T1

Table 1.3.T2

Uses of Task Analysis Data in System Development. (After Reed (1967); modified.)



7. Probabilistic Risk Assessment

The task analysis identifies the different behavioural and information processing activities of the operators and thus provides the basis for estimating the probability of error from human performance data. TA is the basis for sound human reliability analysis in PRA.

8. Link Analysis

This is a procedure by which a graph or matrix is used to describe the movements of people around the control room. In one form an arrow is drawn from the position at which an operator stands when performing an action to the next position to which he moves. Each arrow is marked with a number which shows the number of times the operator made that particular movement. In another version the thickness of each arrow is proportional to the number of times that movement is made. These data reveal physical bottlenecks in the control room, positions where people may be impeded in their movements by equipment or other people, with consequent delays, and danger of inadvertently bumping into controls as they move around the room. The data can thus be used for reconfiguring the layout of the control room.

9. Time Line Analysis

This is a method for estimating operator workload. The duration of each action is marked on a chart in such a way as to reveal the number and duration of occasions on which more than one action is required of an operator at the same time. From the time-line it is possible to derive a probability distribution describing the probability of simultaneous demands on the operator. Workload can be defined in terms of this probability, which in turn can lead to task re-designing or changes in manning levels. Time Line Analysis is extensively and successfully used in the aerospace industry to determine manning levels and to evaluate control panel designs.

1.4 Cost Effectiveness

The question of cost effectiveness is one which is frequently raised by those industries considering undertaking a task analysis. TA is certainly costly. Even with a good and detailed manual it should not be carried out by untrained personnel. To quote Miller again,

> "It is felt that the analysis of human behavior requires a specialist in much the same way that the analysis of machine behavior requires a specialist. In fact, the complexities of human behavior, its great capacity for varied response and its information-handling capacity, may make it even more deserving of a technical specialist.
>
> It is therefore recommended that the following procedures be used by specialists in human behavior. These specialists will presumably be engineering psychologists....
>
> It is not proposed that, because task analysis procedures have been formalized in the following pages, task analysis has been reduced to no more that a rote or mechanical process. The procedure must rather be considered a guide to observation and analysis, not a substitute for

> it. It should permit an orderly approach to the determination of highly complex behaviors, many of which may interact with each other in job performance. We can hope that as additional information about various tasks becomes available through the use of these and related procedures, task analysis can become more and more routinized so that eventually people with less specialized training can perform task analyses appropriate to their purpose."
>
> (Miller, 1953)

A practical problem in the Canadian setting is that there are rather few such qualified human factors specialists, and even fewer are familiar with the nuclear industry. A TA specialist will require time to become familiar with an industry, and the alternative, that a utility have some of its own personnel trained in TA, is also costly, although in the long run cheaper and more desirable.

A full scale CRDR for all the emergency operating procedures (EOP's) of a NPP will require several person-years of work by specialists and will cost several hundreds of thousands of dollars. Burgy et al (1983, NUREG/CR-3371) state that there are 4,000 tasks in a complete TA of a light water reactor, when both EOPs and normal operations are included. If a computer data base must be specially developed the cost will be even higher. The benefit side of the balance is in one sense obvious. The events at Three Mile Island have shown that a seriously flawed control room design can cause an accident with associated costs in the hundreds of millions of dollars. Moreover in the climate prevailing at the time of writing, one more such accident by any utility anywhere in the world may result in the instant demise of nuclear power. There are however more tangible returns. For example, DOE/EP-0095, "Guidelines for Job and Task Analysis for DOE Nuclear Facilities" (1983) contains the following passage.

> "A few years ago a major communications company developed and presented a 10 week training course ..... A later analysis of the course revealed that at least five weeks of the course were being spent teaching irrelevant material. The course was redesigned ..... The development costs though a substantial $350,000 -- paid off. Reducing the course from 6 weeks to an average of 2 weeks resulted in savings of over $4 million a year ..... This company reported that in one six-year period, there was a total saving of $37,800,000 ..... Recently a large public utility's analysis of corporate training led to the following results: "With a few recent changes, the Nuclear Generation group is saving over one million dollars annually with reduction in training to their professionals and trade groups. ..... Just two training decisions for a trade group in our Thermal Generation Division has led to an annual savings of $186,000."

Although these examples refer primarily to training, we have pointed out earlier that the results of a TA carried out for one purpose -- such as CRDR -- inherently contain the possibility of an impact in other areas. Furthermore, if TA is incorporated in the original design process, its cost will be relatively negligible. That is, by identifying problems early and accurately, the ultimate development cost may well be reduced. In terms of retrofitting control rooms after a CRDR, TA should at least help to ensure not merely that any shortcomings are indeed cured, but that in doing so the designers do

not inadvertently create new ones. This is particularly true when a good computer data base management system is available.

1.5 Products of This Contract

This document contains five main products.

1. A detailed method for preparing for a task analysis.

2. A Task Data Form for recording task analysis data.

3. A detailed method for carrying out task analyses.

4. A guide to assessing alternative methods for performing task analyses if such are proposed for utilities or consultants.

5. An annotated bibliography on task analysis.

Care has been taken to consider possible problems which may arise in TA for "advanced" control rooms designed around computer displays and automatic systems. No published method has specifically dealt with this problem. Some indication is given of desirable properties of a data base management system for handling the results of a task analysis, although it has not been possible within the scope this contract to develop plans for such a system in detail. A generic guide is also provided to the preparation required prior to the start of the TA, and an indication of how its output may be used for purposes other than the CRDR for which it is performed.

2.0 METHODS OF TASK ANALYSIS

This section of the report defines and examines two approaches to task analysis, the "descriptive" approach, (which examines what operators actually do), and the "prescriptive" approach, (which examines what they should do) in the light of the AECB's regulatory style. The distinction is important, and is fundamental to understanding the nature of results of a TA, and what can be concluded therefrom.

2.1 "Prescriptive" and "Descriptive" Task Analysis

Consider a situation in which one borrows a car from a friend and wishes to know how to start it on a very cold winter's morning. Two methods suggest themselves as a way of analyzing this task. The first is to read the owner's manual. The second is to observe the friend as he starts it. Typically the manual will contain a passage similar to the following:

> "Fully depress the accelerator twice. With the gear in neutral, turn the ignition key and hold it in the fully clockwise position until the engine fires. Do not depress the accelerator. When the engine temperature is normal, engage gear and drive off."

That description is the basis for a prescriptive task analysis. Examining it in detail in relation to the displays and controls of the vehicle will provide an analysis of how the task ought to be done, as described by the manufacturer of the hardware and the writer of the procedures. The assumption is that if the procedure is carried out as stated in relation to the hardware as provided, efficient and safe operation will result.

On the other hand, if we observe the car's owner starting it, we may typically observe that he depresses the accelerator several times rapidly, turns the ignition key, and as soon as the engine fires pumps the accelerator vigorously, and without waiting for the engine to warm up properly, he engages gear and drives off.

A description of what he does would yield a descriptive task analysis. It would describe what the operator actually does in practice.

The difference is significant. In descriptive task analysis we may find behaviour which accomplishes the operator's goal, but which is non-standard. A descriptive task analysis cannot show whether there are some operations for which no procedures exist. It cannot show whether there are any properties of the person-machine system which the hardware designer intended the operator to know but which have been omitted from the procedures manual and/or training.

A descriptive task analysis can only record what actually happens during the course of the analysis, not what might happen or fail to happen under conditions which the operator has never experienced.

A descriptive analysis is therefore very limited, and is not sufficient for the purposes of the AECB in control room design review. An example of a descriptive task analysis is given by Burgy et al (1983) in NUREG/CR-3371.

A well conducted prescriptive task analysis can in principle answer all the questions which a descriptive task analysis cannot. Most importantly it can describe what the

designer, trainer, procedure writer and management require to happen in the case of events which no operator has ever in practice experienced, and it can discover cases where procedures have been overlooked and which are missing although intended by the hardware designers. Examples of prescriptive task analysis methods are given by Analysis Technology, Inc. in DOE/EP-0095 and by the Institute of Nuclear Power Operations in INPO 83-046 (NUTAC).

The method we describe in this document is primarily a prescriptive method, although it contains descriptive elements. It thus has the virtues of both approaches. This is of great importance, since for certain kinds of tasks, particularly associated with advanced control rooms and automatic systems where the operator is mainly a fault detector and fault manager rather than a process controller, no descriptive task analysis is possible. Most of the operator's time is spent in observing data and thinking about their implications. The "behaviour" is largely cognitive, and since it takes place within the operator's head, there is little overt behaviour to observe and describe. The only approach available is through a logical analysis of the results of a prescriptive task analysis.

2.2 NOTE: "PRESCRIPTION" AND REGULATORY STYLE

The regulatory style adopted by the AECB does not "prescribe" in detail what the utility must do, but calls on the utility to justify whatever choice the latter may make with regard to any issue.

It is therefore important to note that in calling the method we recommend a "prescriptive task analysis", we are not saying that it is the method which should be prescribed by the AECB as the only acceptable method of TA for use by utilities.

A prescriptive task analysis refers to the relation of the task analysis method to the data used in the task, not to the choice of the task analysis method. Many different prescriptive task analysis methods can be designed, and a utility may well propose an excellent and acceptable prescriptive alternative to that adopted by the AECB.

The adjective "prescriptive" refers to the fact that the aim of the analysis is to establish what behaviour is prescribed for the operator by the utility, rather than describing the behaviour found in practice in the control room or simulator.

3.0 CONSIDERATIONS IN THE SELECTION OF A PREFERRED TASK ANALYSIS METHOD

This section examines the structure of TA, and looks closely at three methods which have been proposed for nuclear CRDRs in the U.S.A. Their virtues and shortcomings are listed. Examples of various steps in a TA are given, together with criteria to be used in assessing the quality of a TA team and the work produced. A most important component of a TA is the Task Data Form (TDF) onto which data are entered into the overall database. A preferred TDF is recommended.

3.1 Introduction: Existing Methods for Nuclear Task Analysis

None of the three methods which have been described specifically for use in the (American) nuclear industry is completely suitable as it stands. The purpose of this chapter is to describe how a task analysis is performed, and to synthesize one that is suitable for the needs of the AECB. Appropriate components will be taken from each of the three existing methods and will be supplemented with new methodology where required. The most influential document is DOE/EP-0095, of which a microfiche is provided in the back cover of this document. A comparison of the three methods published in the U.S.A. for use in nuclear TA is provided in table 3.1.T1.

3.2 Factors to Consider in Choosing or Designing a Task Analysis Method

3.2.1 Levels of Analysis

The aim of a prescriptive task analysis is to describe exactly what an operator is required to do to carry out a task. To do this means that the task is identified as relevant for that operator from the operator job description. The task is then described in terms of its subtasks (if any), and finally at the level of its elements. The actions of the operator by which the elements of the task are performed are the final data of the first stage analysis. From those data further analysis can be designed and recommendations can be made. It is useful, because of the complexity of a NPP, to relate the task to the job through the duty area or location where it is carried out. (See Figures 3.2.1.F1, 3.2.1.F2)

It is necessary to consider each step of this process systematically and in detail. It is sometimes assumed that the operating procedures can be used as a complete description of tasks, or the job description to contain a complete list of tasks. Neither assumption is safe. Changes may have occurred without being documented. There may have been omissions at the time the job description was drawn up, or at the time the procedures were written.

Operators may informally have developed different practices at the level of elements. In all cases the written documents provided by the utility must be supplemented by systematic review by the task analysis team.

Table 3.1.T1 Comparison Between INPO-83-046, NUREG/CR-3371 and DOE/EP-0095.

CRITERIA	¶ INPO-83-046 Control Room Design Review Task Analysis Guidelines
1. Type of Task Analysis	Prescriptive - Descriptive
2. Approach	Use of four increasingly comprehensive methods of task analysis that can be used in combination. Starts with a paper and pencil method and can extend to a full simulator analysis. Can be carried out in a four stage approach. This approach allows greater emphasis on prescribing what should be done, and the use of descriptive methods to validate the former's results. Uses a system approach.
3. Problems	Methodology is somewhat open ended. Not enough discussion as to how to decide on which combination of methods (paper-pencil, table-top, walk-through, simulator) are to be used for a particular application. Flexibility of method may leave it open to misuse.
4. Assets	The method is described in a plain-language manner that is clear and understandable. It is layed out in an easy-to-follow manner. Good examples to illustrate the methodology. The method allows for flexibility so that it may be applied to various situations and plant conditions (e.g. automated and manual systems).
5. Data Collection Methods	- Examination of procedures and system plans - Interviews with experts and operators - Table-top discussion with subject matter exper - Walk-through/talk through - Video & personal observation - Simulator PMS - Questionnaires
6. Data	Complete prescriptive and descriptive data.

Table 3.1.T1 cont d — Comparison Between INPO-83-046, NUREG/C 3371 and DOE/EP-0095.

CRITERIA	¶ INPO-83-046 Task Analysis of Nuclear Power Plant Control R
7. Extent of Work	Depending on what combinations of stages used, the method requires from one to many well trained, experienced analysts. The method can be labour intensive. The length of time to complete the analysis also depends on the choice of the stages and their combinations. To complete all of the stages would require almost a year, using many analysts on the project.
8. Resources	- Simulator - Computer - Video Equipment - Mock ups
9. Computerizaton	Uses full scale data base at INPO available to utilities. See example - excellent prescriptive data base.
10. Involvement	Requires help of: - System engineers and designers - Operators and supervisors - Training staff - Plant management
11. Examples provided - documents	List

Table 3.1.T1 cont'd — Comparison Between INPO-83-046, NUREG/CR-3371 and DOE/EP-0095.

CRITERIA	¶ NUREG/CR-3371 Task Analysis of Nuclear Power Plant Control Room Crews
1. Type of Task Analysis	Descriptive with a prescriptive component.
2. Approach	Also uses the four stage concept though the paper and pencil stage is included in the second stage - table top analysis. More emphasis is placed on the latter stages. Hence, the method tends toward describing what the operators are doing or feel they should do rather than what design principles state. Does not provide for validating methods, though these would be easy to integrate with the method.
3. Problems	Methodology is not described clearly enough. The actual approach that appears to be used is not the one described. The results given as an example of output appear to represent only descriptive information. The task sequences do not appear to represent only descriptive information, nor do they appear to represent prescribed sequences. Level of detail also appears to be too gross. Report is poorly organized and hard to follow.
4. Assets	Provides excellent descriptive data that is complete and machine ready. Uses Berliner behavioural categories and a well defined vocabulary. Hence, the inter-observer and inter-analyst reliability will be high. Method is easy to validate for above reasons and due to its rigid approach.
5 Data Collection Methods	- Examine procedures training guidelines systems plans, etc. - Interviews with experts and operators - Table-top discussion with experts - Walk-through/talk-through - Video and personal observation - Simulator PMS
6. Data	Complete descriptive but incomplete presciptive data.

Table 3.1.T1 cont'd — Comparison Between INPO-83-046, NUREG/CR-3371 and DOE/EP-0095.

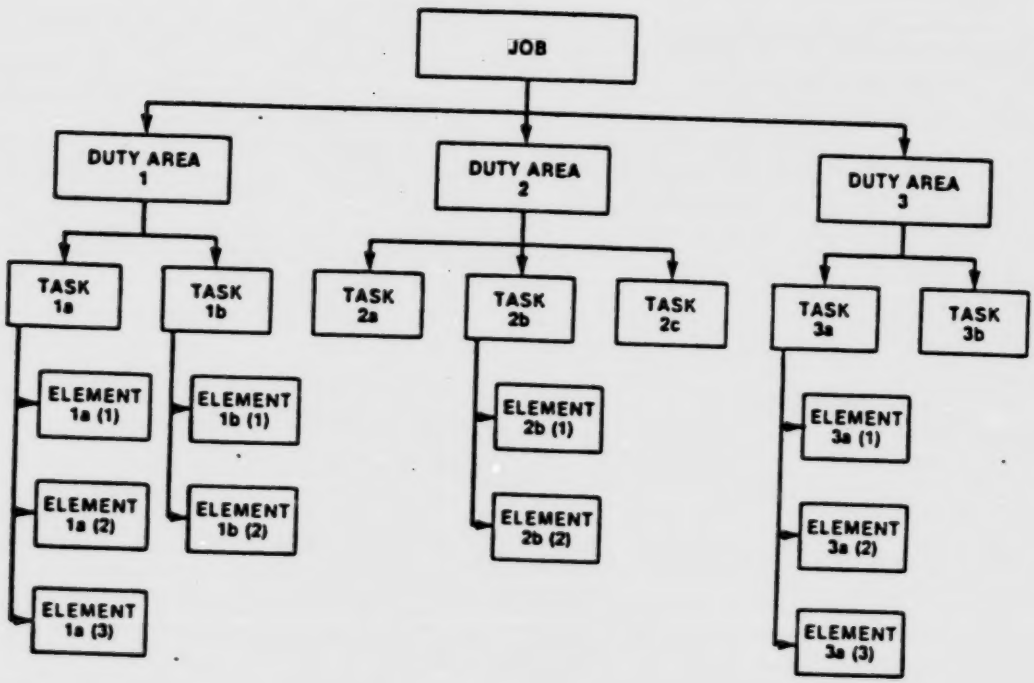
CRITERIA	¶	NUREG/CR-3371
7 Extent of Work		As with the INPO task analysis. this method involves the use of many well trained, experienced analysts. Similarly. it also requires a long time frame for completion from 6 months to a year.
8. Resources		- Simulator - Computer - Video equipment
9. Computerization		Uses the SEEK system run on a PRIME 1 computer. Provides - Link analysis - Time line analysis - Human reliability analysis
10. Involvement		Require help of: - Plant management - Operators and supervisors - Training staff - System engineers and designers
11. Examples provided - documents		List

Table 3.1.T1 cont'd — Comparison Between INPO-83-046, NUREG/CR-3371 and DOE/EP-0095.

CRITERIA	DOE/EP-0095 Guidelines for Job and Task Analysis for DOE Nuclear Facilities
1. Type of Task Analysis	Prescriptive with applicability to descriptive.
2. Approach	Uses 4 stage including "duty area" - finer gradation than INPO. Although designed for use in DOE nuclear facilities it is more general than INPO. Emphasis towards training, but has sections on CRDR and PRA. Better description than INPO of choice of personnel and their roles in TA. Good discussions of validation and verification. Good discussions of method, and unique in describing scheme for training those who will carry out the task analysis. Good description of how to develop taxonomy and computerized data base. Includes "paradigming" - what to do when in the course of a TA a situation is found for which no procedure exists.
3. Problems	Relatively little concentration on nuclear applications, despite its being written for DOE nuclear facilities. Relatively few examples of output of TA in a nuclear content, but probably sufficient to show how the general principles apply. Little on how to do descriptive recording (video, film, etc.) or how to analyze the latter.
4. Assets	Particularly detailed discussin of how to carry out interviews. how to train TA team, how to formulate questions. Gives an estimate of person days required for some phases. Gives impressive examples of cost savings achieved through application of TA. Emphasizes systems approach involving designers, trainers, operators, etc. Comments on relative labour-intensiveness of different phases and different methods. Describes how to develop a taxonomy and set up a computer data base. Discusses "paradigming" - what to do when procedure is found for an action while carrying out a TA.

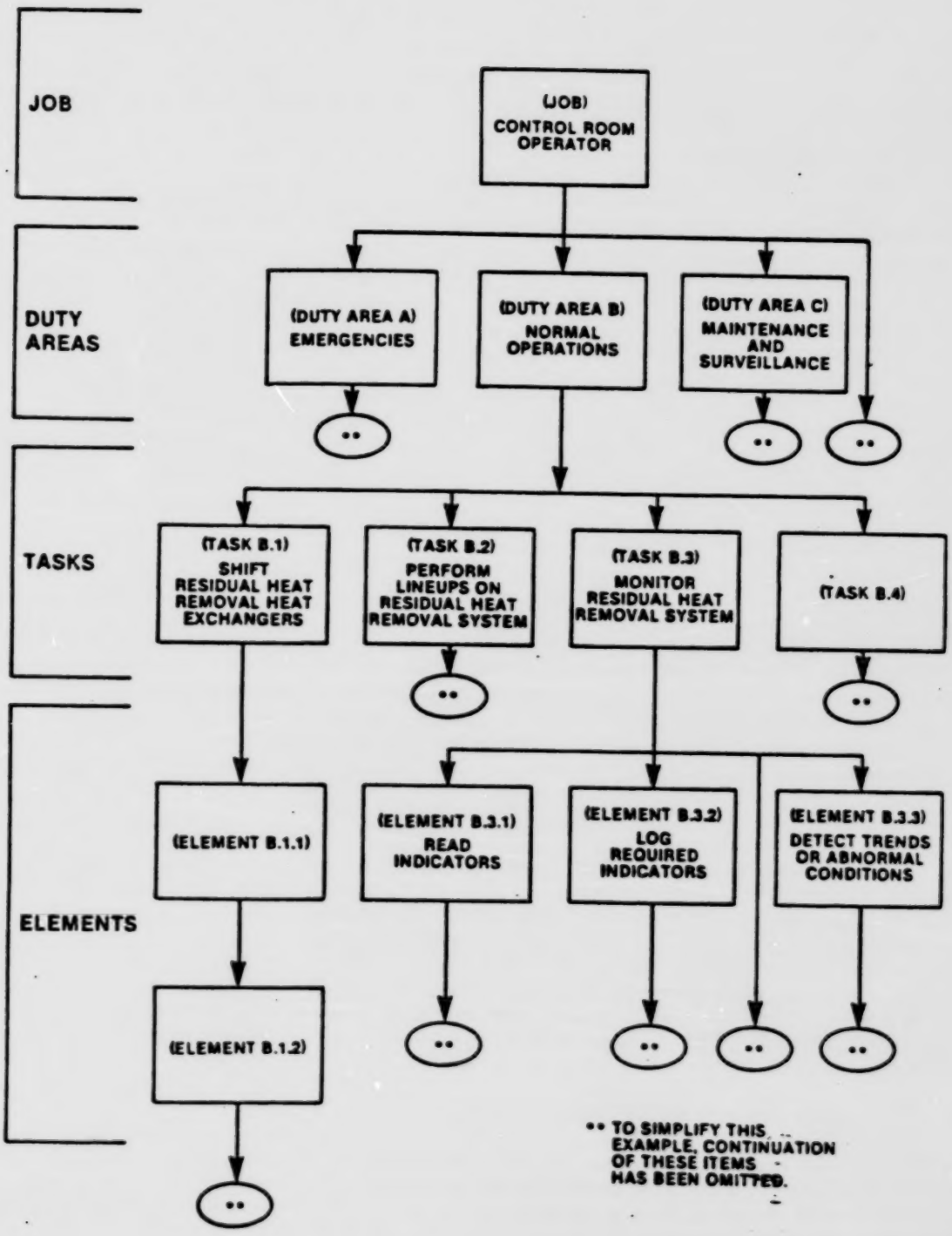
Table 3.1.T1 cont'd — Comparison Between INPO-83-046, NUREG/CR-3371 and DOE/EP-0095.

CRITERIA	¶	DOE/EP-0095
5. Data Collection		- Examine procedures, design manuals, control rooms. - Table top without subject matter experts - Walk-through/Talk-through - Simulator - Control Room - Interviews - Questionnaires
6. Data		Complete prescriptive (with application in principle to descriptive).
7. Extent of Work		Gives an outline of expected manpower requirements, how to train them, expected training time. Provides exercises for training TAs. No direct estimates of overall time frame, but no reason to assume any difference from other methods. Does give estimates of length of preliminary steps.
8. Resources		- Simulator - Computer - Mock ups - Video equipment
9. Computerization		Discusses with examples how to design a taxonomy, and what to look for in a computerized system. Emphasizes the importance of good data base management to allow efficient recovery of data. Discusses principles rather than advocating or providing a specific system.
10. Involvement		- Subject matter experts - Plant management - Design engineers and systems engineers - Operators and supervisors - Training staff - Emphasis on total systems involvement - not just operators



Interrelationships of Job, Duties, Tasks and Elements.
(From DOE/EP-0095)

Figure 3.2.1.F1


JOB
DUTY AREAS
TASKS
ELEMENTS
(JOB) CONTROL ROOM OPERATOR
(DUTY AREA A) EMERGENCIES
(DUTY AREA B) NORMAL OPERATIONS
(DUTY AREA C) MAINTENANCE AND SURVEILLANCE
(TASK B.1) SHIFT RESIDUAL HEAT REMOVAL HEAT EXCHANGERS
(TASK B.2) PERFORM LINEUPS ON RESIDUAL HEAT REMOVAL SYSTEM
(TASK B.3) MONITOR RESIDUAL HEAT REMOVAL SYSTEM
(TASK B.4)
(ELEMENT B.1.1)
(ELEMENT B.1.2)
(ELEMENT B.3.1) READ INDICATORS
(ELEMENT B.3.2) LOG REQUIRED INDICATORS
(ELEMENT B.3.3) DETECT TRENDS OR ABNORMAL CONDITIONS
** TO SIMPLIFY THIS EXAMPLE, CONTINUATION OF THESE ITEMS HAS BEEN OMITTED.

Hierarchical chart of Control Room Operator Job and Task Breakdown.
(From DOE/EP-0095)

Figure 3.2.1.F2

3.2.2 Personnel Required for Task Analysis

People who may be involved in Job and task analysis include the following.

1. The Task Analysis Team

Human factors research or application is not a matter of common sense and a handbook, but should be done by human factors/ergonomics specialists. The exact wording of questions, the order in which they are asked, etc. all play a major role in the nature, quality and quantity of answers received. An excellent discussion of this point is available in the appendices of DOE/EP-0095. If an organization does not contain trained specialists they must be acquired on a consulting basis, or a senior experienced human factors specialist should be hired to train and oversee inhouse staff. DOE/EP-0095 contains an excellent account of how to train personnel. Such training should be undertaken by human factors specialists with an academic training in the application of behavioural and other sciences to the design and evaluation of technological systems with human operators and maintenance personnel. It is not sufficient merely to designate a staff engineer as responsible for this work by management fiat with no training.

2. Subject Matter Experts (SME)

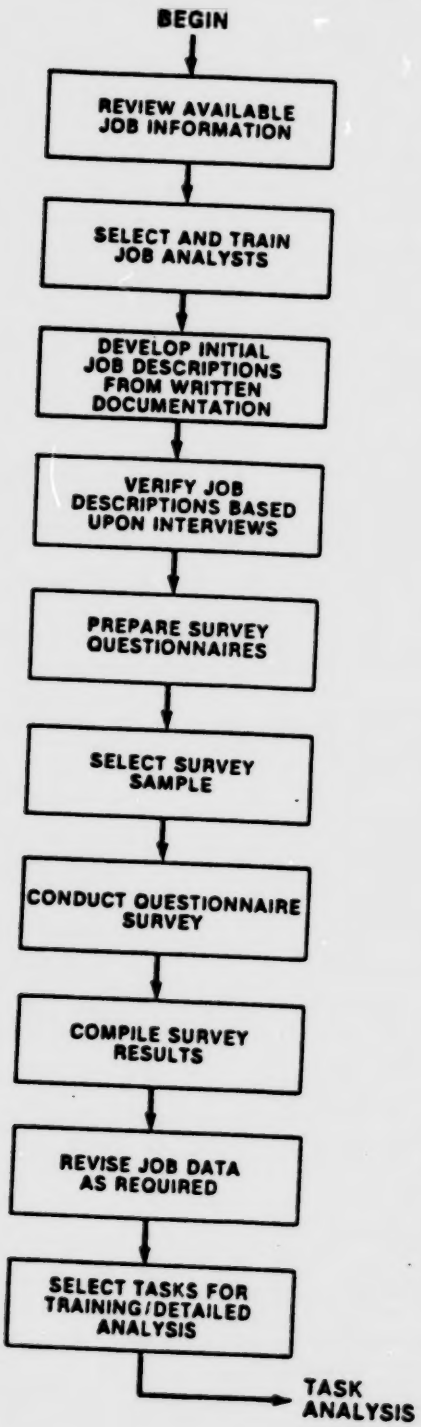
These are people such as operators with experience of at least 2 years in the jobs and tasks involved. Also included are design engineers, those responsible for training, supervision and maintenance, procedure writers, and management. Opinions, facts and data may be needed from any or all of these to ensure that no jobs, tasks, or elements are overlooked, and to resolve ambiguities. The amount of time for which each kind of SME may be required will vary greatly. In general the closer to the critical operation a person is the longer that person will have to be available. More than one of each kind of SME is desirable to increase the reliability of the analysis by cross checking.

3. Operators

One or more control room operator teams will be required for an extended period. If possible a team of experienced operators containing people with more than two years experience in each job should be allocated to work with the task analysts for the duration of the analysis. This will improve communications and lead to mutual trust. This latter point is very important. If an operator has developed (and uses) non-standard operating procedures, he may not describe them if he feels that management will discover it through the analysis, and that this will lead to his being reprimanded or punished. (DOE/EP-0095 suggests that the "interview" stage of the investigation be 2 - 4 weeks.)

3.2.3 Job Analysis -- Input to Task Analysis

The aim of job analysis is to list all the tasks which a person having a particular job may be required to do. The recommended sequence of activities in job analysis is shown in Figure 3.2.3.F1, from a description in DOE/EP-0095. It is important to realize that if the task analysis team is drawn from outside the utility the job analysis has the added virtue of making them acquainted with the location, facilities, personnel, vocabulary, and work philosophy of the job. The cost involved in performing a thorough



Flow chart for preparations required for task analysis.
(From DOE/LP-0095)

Figure 3.2.3.F1

Job Analysis will be repaid in the quality of the task analysis. Furthermore, the choice of which tasks to analyze in detail can only be made on the basis of job analysis, since not all tasks can be analyzed. Again it is to be emphasized that only by very systematic analyses can accurate data be acquired in complex jobs and tasks. Furthermore, Job Analysis may reveal high level interactions between operations which are not apparent at the task level. Is there, for example, any task which can be carried out by <u>any</u> qualified operator, but not by a particular operator? At the task level this may appear as a simple single-operator task. But at the job level it may become apparent that the process of deciding which operator will perform the task is itself a task of some complexity which could produce undesirable delays and uncertainties.

Between the outright emergency condition and the normal operating there is a "grey area" of plant states which are non-normal or abnormal and about which something must be done to restore the plant to normal conditions or to bring the plant to a safe cool state. For such plant states there are not, in all probability, specified operating procedures if only because of the very large number of such possible states and the labour involved in determining the appropriate operator procedures. It may well be the case, for some such states, that they are not identifiable in advance of their occurrence and that no procedures could be written for them.

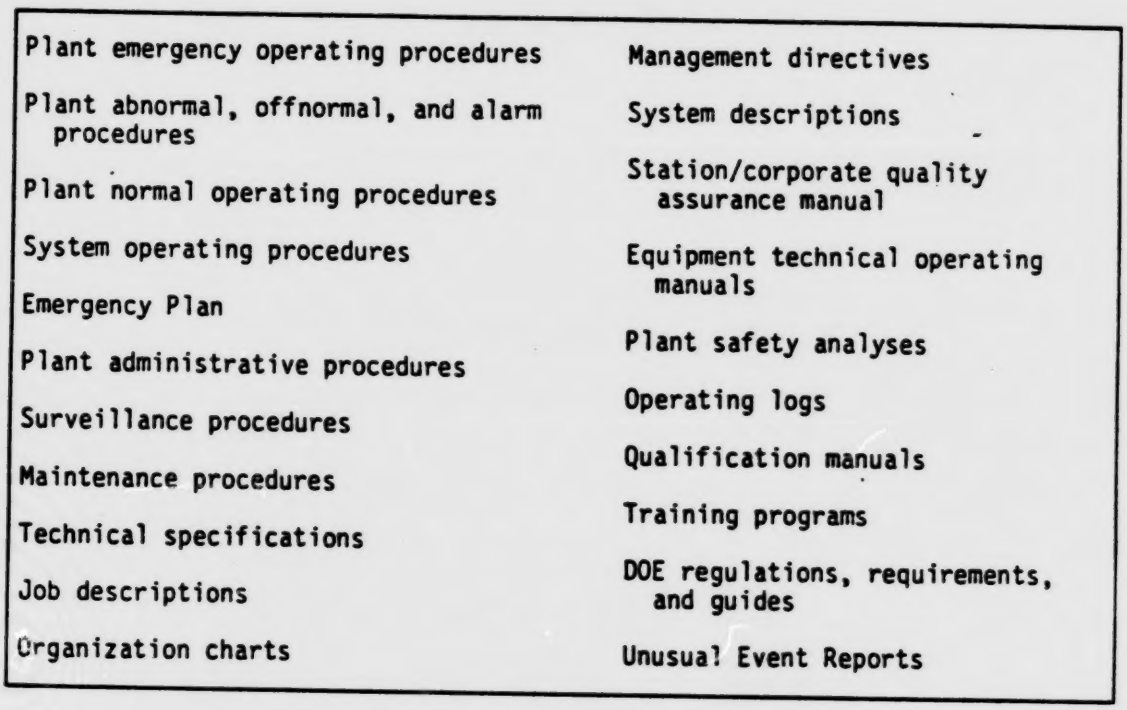
It is also the case that there are plant states which are non-normal and for which no appropriate diagnostic procedure exists.

It may be necessary in such cases for the utility to specify generic procedures which should be used by the operator to proceed in a symptom-based manner either to diagnose the problem while keeping the plant in a state from which it can Fig. 3.2.3.F1 be taken to safe shut-down, or to proceed directly to safe shut-down. In either case the TA will analyze the elements of the procedures, or will indicate that the procedure is not well specified, and thus draw attention to the need for development of policy, procedures and training. Particular care is needed by the TA team over this type of task, since it may, almost by definition, be characterized by the absence of details. The team should take special care to include such tasks in their analysis.

Figures 3.2.3.F2 and 3.2.3.F3 show respectively the kind of documents used in job and task analysis and some guidelines for how to write job and task analysis descriptions, see also DOE/EP-0095. Table 3.2.3.T1 shows a typical result of a completed job analysis.

3.2.4 Choice of Tasks for Analysis

Task analysis is resource intensive in terms of the time of the analysts and of the industry personnel. In a system as complex as a NPP where the number of operating procedures may run into the hundreds or even thousands not all tasks can be fully analyzed. It follows that a major byproduct of the task listing which occurs during the job analysis is a decision as to what tasks should be analyzed in detail. (Note also that if Management and Design Engineers are included in the job analysis survey and interviews it may be discovered that tasks exist which have not been assigned to a job, or which have been given multiple assignments.)



Source materials required for job and task analysis. (From DOE/EP-0095)

Figure 3.2.3.F2

REQUIREMENT	TASK STATEMENT	EXAMPLE
Clarity	Use wording that is easily understood.	"Compare written description to actual performance." But Not "Relate results to needs of field."
	Be precise so it means the same thing to all personnel.	Use words such as "check, coordinate, assist" with caution -- they are vague.
	Write separate, specific statements for each. Avoid combining vague items of skill, knowledge, or responsibility.	"Supervise files." "Maintain files." But Not "Have responsibility for maintaining files."
Completeness	Use abbreviations only after spelling out the term.	"Inventory spare parts" may be followed by "Prepare requistions for spare parts."
	Include both form and title number when the task is to complete a form, unless all that is needed is the general type of form.	"Complete Task Description Worksheet (Form No. XXX)."
Conciseness	Be brief.	"Write production and control reports." But Not "Accomplish necessary reports involved in the process of maintaining production and control procedures."
	Begin with a present-tense action word (subject "I" or "you" is understood).	"Clean" or "Write."
	Indicate an object of the action to be performed.	"Clean engine." Write report."
	Use terminology that is currently used on the job.	Use most recent military documentation.
Relevance	Do not state a person's qualifications.	"Load computer tape." But Not "Has one year computer training."
	Do not include items on receiving instruction, unless actual work is performed.	"Prepare lab report." But Not "Attend lecture."

Criteria for descriptions in task analysis. (From DOE/EP-0095)

Figure 3.2.3.F3

JOB CODE: RO

TASK INVENTORY

System Operations

Task Number	Tasks
1.	Primary Cooling Water System
1.1	Start up the primary cooling water system
1.2	Shut down the primary cooling water system
1.3	Start up the pony motor system
1.4	Shut down the pony motor system
1.5	Start an equalizing change of the pony motor system battery
1.6	Stop an equalizing change of the pony motor system battery
1.7	Restart a primary cooling water pump following a failed start attempt
1.8	Conduct operations for abnormal vibration of primary pump and pony motors
1.9	Conduct operations for abnormal vibration of the reactor vessel and primary coolers
1.10	Complete a shift heat balance
2.	Primary Cooling Water System Instrumentation
2.1	Determine that the reactor core coolant temperature instruments have a faulty channel
2.2	Trip a reactor core coolant temperature instrument faulty channel
2.3	Adjust helium flow rate to reactor liquid level bubbler tubes

Example of initial task inventory.
(From DOE/EP-00095)

Table 3.2.3.T1

JOB CODE: RO

TASK INVENTORY

System Operations

Task Number	Tasks
2.	Primary Cooling Water System Instrumentation (Continued)
2.4	Adjust helium flow rate to emergency liquid level bubbler tube
2.5	Place the primary water activity monitor in service
2.6	Remove the primary water activity monitor from service
2.7	Drain the sampling conditioning system filter and resin column
2.8	Determine that a faulty channel exists in the fuel cladding failure safety system
2.9	Trip a fuel cladding failure safety system channel
2.10	Read pump motor bearing oil temperatures
2.11	Adjust the scram settings associated with the primary pumps and pony motors
3.	Secondary Cooling Water System
3.1	Start a secondary cooling water pump
3.2	Restart a secondary cooling water pump following a failed start attempt
3.3	Shut down a secondary cooling water pump
3.4	Start up the secondary cooling water system

(continued)

JOB CODE: RO

TASK INVENTORY

System Operations

Task Number	Tasks
3.	Secondary Cooling Water System (Continued)
3.5	Increase secondary cooling water flow to multiple pump operation
3.6	Reduce secondary cooling water flow to single pump operation
3.7	Shut down the secondary cooling water system
3.8	Switch secondary cooling water pumps
3.9	Switch shutdown cooler secondary effluent to the cooling towers
3.10	Switch shutdown cooler secondary effluent to holdup tank
3.11	Switch shutdown cooler secondary effluent to the storm sewer
3.12	Syphon feed cooling water from the cooling tower basin to the shutdown cooler
3.13	Supply cooling water from collection tank to the shutdown cooler through the crossconnection feed
3.14	Supply domestic water to the shutdown cooler
3.15	Return shutdown cooler secondary effluent to the cooling tower basin from holdup tank using cooling tower emergency pump
3.16	Supply well water to the shutdown cooler
3.17	Disconnect well water supply from the shutdown cooler
3.18	Remove a cooling tower from the Line

(continued)

JOB CODE: RO

TASK INVENTORY

System Operations

Task Number	Tasks
3.	Secondary Cooling Water System (Continued)
3.19	Add a cooling tower to the Line
3.20	Start a cooling tower fan
3.21	Shut down a cooling tower fan
3.22	Reset the cooling tower fan vibration shut-down trip
3.23	Fill the secondary cooling water system
3.24	Drain the secondary cooling water system
3.25	Conduct operations to confirm abnormal shut-down cooler effluent activity and identification of the leaking cooler
3.26	Determine if the secondary cooling water system is receiving the required dosage of water treatment chemicals
3.27	Drain secondary cooling water side of a primary cooler
3.28	Slug feed secondary water chemicals
3.29	Fill secondary cooling water day tanks
3.30	Chlorinate the cooling tower basin
4.	Secondary Cooling Water System Instrumentation
4.1	Obtain a temperature readout from the primary cooler secondary coolant temperature indicator

(continued)

Relevant criteria include the following:

1. Scale and cost of task analysis required. (S)

2. Frequency of occurrence of task. (F)

3. Time pressure on operator (TP) (The more rapidly the task must be completed the more important to analyze it, since it will put pressure on the operator.)

4. Mental (cognitive) workload involved (L)

5. Motor skills required. (M)

6. Seriousness of consequences if carried out improperly. (I)

7. Amount of training required. (T)

Ideally these qualities of a task should be quantified and combined in a polynomial equation:

$$U = bf + cTP + dL + eI + fM + gT - aS$$

and those tasks with a high U value are chosen for analysis. Note that S has a negative weighting, suggesting that the more costly a particular analysis the less desirable it is. While this is clearly true, the coefficient a should be given a very low value, since if the consequences of an error in a task are high, (for example release of significant radioactivity to the environment) it must be analyzed at whatever cost. Note also that the weighting of F is difficult to determine. The more frequent a task the more important it would seem to analyze it. On the other hand infrequent tasks are more likely to be poorly performed, due to lack of practice. It appears from the literature that no one has proposed such a quantitative equation. It is here suggested as an heuristic to aid decision making. Table 3.2.4.T1 shows some suggestions for scaling the variables involved, Table 3.2.4.T2 shows a decision using some of the variables listed above. Table 3.2.4.T3 gives an estimate of the time required for the questionnaire/interview stage of the task analysis.

The choice of task is essentially a matter of cost/benefit analysis. A good TA method will be able to handle any task proposed.

3.2.5 Definitions, Vocabulary, and Task Data Form

The quality of task analysis data is strongly dependent on decisions made about the use of language and methods to record data. The degree of detail, the reliability of the data, and the validity of the data are all affected. Table 3.2.5.T1 is an example of a Task Data Form (TDF) as used by Burgy et al in NUREG/CR-3371, and in Table 3.2.5.T2 is the same form at the end of a task analysis. (This form is not the one which will be recommended and is given at this point purely to develop the discussion.)

FREQUENCY

Min. 1. "Less than once per year."

2. "Annually/semi-annually (5-12 months)."

3. "Monthly/quarterly (3 weeks - 4 months)."

4. "Weekly/bi-weekly (1-2 weeks)."

Max. 5. "Daily (or more frequently than once per week)."

TASK IMPORTANCE

Min. 1. Consequences of improper performance are "negligible" (for example, improper performance makes almost no difference in plant operation).

2. Consequences of improper performance are "undesirable" (for example, impairment of a safety system function may result).

3. Consequences of improper performance are "serious" (for example, an unusual occurrence event may result).

4. Consequences of improper performance are "severe" (for example, an alert event may result).

Max. 5. Consequences of improper performance are "extremely severe" (for example, a site or general emergency event may result).

DIFFICULTY OF PERFORMANCE

First, decide if the task performance requires a high, medium, or low degree of mental activity. A high mental activity rating will use either "5" or "4", medium, a "3"; and low, a "2" or "1". The amount of motor coordination required will resolve using "5" or "4" and "2" or "1" (a medium mental activity uses a rating of "3" irrespective of motor coordination).

Min. 1. "Low" mental activity and "low" motor coordination are required.

2. "Low" mental activity and "high" motor coordination are required.

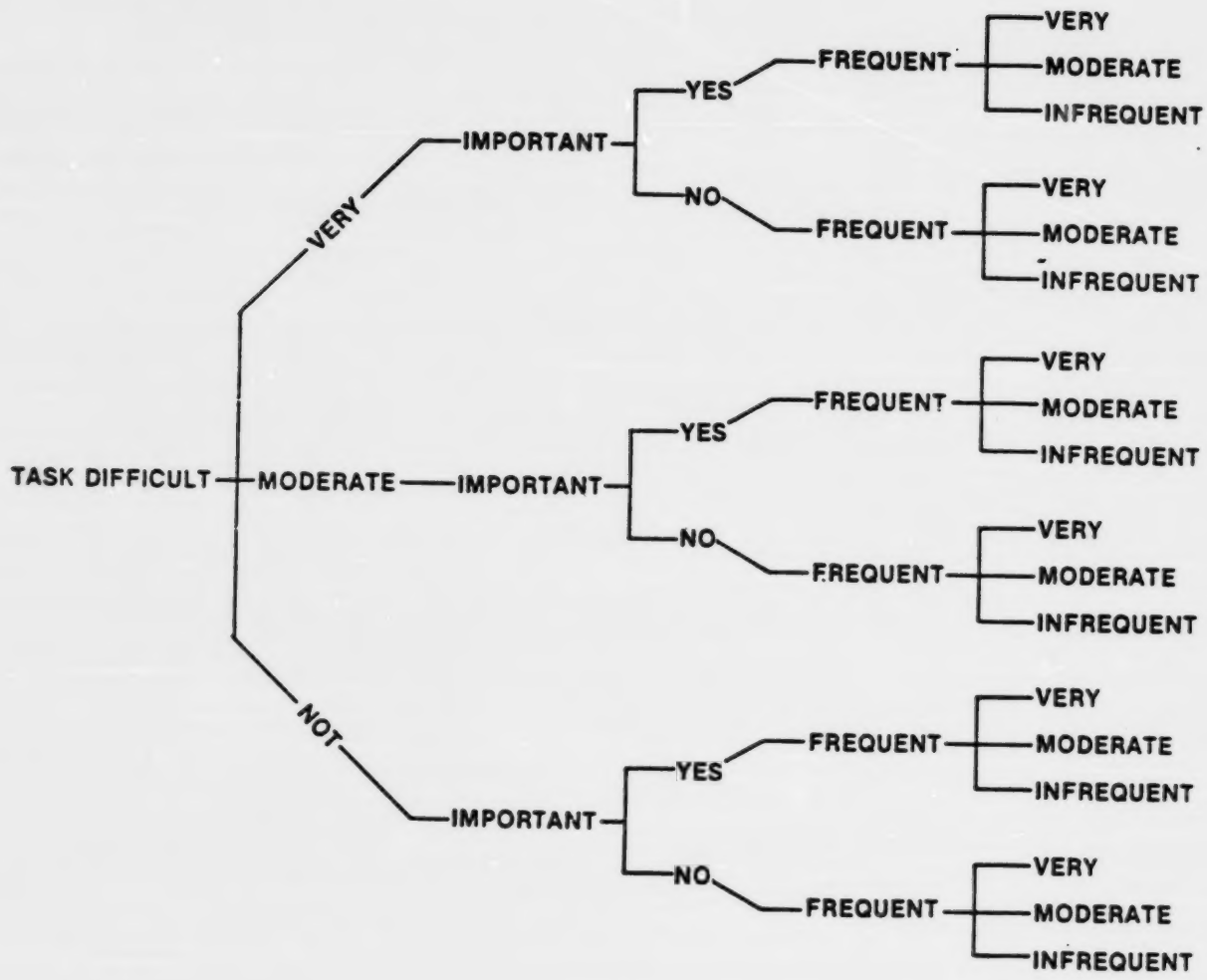
3. "Medium" mental activity is required (irrespective of the degree of motor coordination needed).

4. "High" mental activity and "low" motor coordination are required.

Max. 5. "High" mental activity and "high" motor coordination are required.

Criteria for choosing tasks for analysis II
(From DOE/EP-0095)

Figure 3.2.4.T1



Criteria for choosing tasks for analysis. I
(From DOE/EP-0095)

Table 3.2.4.T2

TYPE OF TASK	LEVEL OF EFFORT PER TASK (hr)
1. System Operations, Routine Non-Specific, Administration	5.0
2. Maintenance and Surveillance	8.5
3. Team Evolutions	12.0
4. Emergencies and Abnormals	18.0 if normal approach 32.0 if paradigming used

Estimate of time required for performance of task analysis interviews.
(From DOE/EP-0095)

Table 3.2.4.T3

TASK DATA FORM (DESCRIPTIVE)

Page No. _____

PLANT IDENTIFICATION

Plant Name _____

Unit Number _____

NSSS Vendor _____

A-E _____

TG Vendor _____

CR Type _____

OL Date _____

TASK IDENTIFICATION

Operating Sequence _____

Operating Sequence ID _____

Operator Function _____

Operator Sub-function _____

Comments _____

CUE _____

Task Statement _____

Task Purpose _____

INPO Task Code _____

Task Sequence No. _____

Task Duration _____

Procedures _____

Data Collected at: _____

Who Takes Action JOBCAT	Location of Means of Action LOC	Behavior		Object of Action						Means of Action MEANS	Communication Link		
		TIME	VERB	COMPONENT	PARAMETER	STATE	OTHER OBJECT	PLANT SYSTEM	INPO EQUIV		RESPONS.	PLOC	CONTENT

Example of Task Data Form for a descriptive task analysis.

(From NUREG/CR-3371)

TASK DATA FORM (DESCRIPTIVE) ITEM ID 75-12-02

PLANT IDENTIFICATION

Plant Name 75

Unit Number 1

NSSS Vendor C-E, PWR

A-E BECHTEL

TG Vendor G-E

CR Type SINGLE

OL Date 830000 (EST)

Data Collected at: SIMULATOR

TASK IDENTIFICATION

Operating Sequence CHEMICAL VOLUME CONTROL SYSTEM MALFUNCTION

Operating Seq ID 12

Operator Function: SUPERVISE AND CONTROL PLANT OPERATIONS

Operator Sub-Function: MITIGATE CONSEQUENCES OF AN ACCIDENT

Comments:

CUE: HIGH TAVE VERIFIED

Task Statement MANUALLY INSERT CONTROL RODS

Task Purpose: TO BALANCE TURBINE AND REACTOR

Task Sequence No.: 02

INPO Task Code CRO-1.29-0

Task Duration: 00:02:19

Procedures: POWER OPERATIONS 41OP-1ZZ05

		Behavior		Object of Action						Communication Link			
JOBCAT	LOC	TIME	VERB	COMPONENT	PARAMETER	STATE	OTHER OBJ.	SYSTEM	INPO	MEANS	RESPOND	RLOC	CONTENT
SRO-1	34	00 01 32- 00 01 35	DIRECTS							VERBAL	RO-1	CR	INSERT CONTROL RODS
RO-1	30	00 01 37- 00 02 24	ADJUSTS	CONTROL ROD	POSITION	IN		CEDMCS	001	CONTINUOU SLY VARIABLE CONTROL			
RO-1	30	00 01 37- 00 02 24	MONITORS				TAVE/TREF			RECORDER			
RO-1	30	00 01 37- 00 02 24	MONITORS	CONTROL ROD	POSITION			CEDMCS	001	DIGITAL DISPLAY			
RO-1	30	00 01 37- 00 02 24	MONITORS	REACTOR	POWER	VALUE		RCS	002	METER/REC ORDER			
RO-1	30	00 02 27- 00 02 28	INFORMS							VERBAL	SRO-1	CR	TEMPERATURE COMING DOWN
RO-1	30	00 02 52- 00 02 55	OBSERVES				TAVE/TREF			METER/REC ORDER			
RO-1	30	00 02 56- 00 03 26	ADJUSTS	CONTROL ROD	POSITION	IN		CEDMCS	001	CONTINUOU SLY VARIABLE CONTROL			
RO-1	30	00 03 03- 00 03 08	INFORMS							VERBAL	SRO-1	CR	REACTOR POWER AT 101%
RO-1	30	00 03 08- 00 03 10	REQUESTS							VERBAL	RO-2	CR	TURBINE LOAD STATUS
RO-2	28	00 03 11- 00 03 14	INFORMS							VERBAL	RO-1	CR	TURBINE LOAD STABLE
RO-1	30	00 03 42- 00 03 53	INFORMS							VERBAL	SRO-1	CR	AT 100% TEMPERATURE AND POWER STABILIZED

Example of completed Task Data Form for a descriptive task analysis.
(From NUREG/CR-3371)

A single entry in the TDF consists (in NUREG/CR-3371) of the following fields:

JOBCAT - whose job is it to perform the task? - RO-1, "First Reactor Operator"

LOC - which position in the control room is the operator occupying when he performs this element? - "30" as listed on a plan of the control room.

TIME - since the start of the task - "00:02:56" in hours, minutes and seconds

VERB - what it is that the operator does - "ADJUSTS", a generic verb which can be used with any appropriate specific noun.

COMPONENT - a task specific noun indicating what it is that is affected by the verb - "CONTROL ROD"

PARAMETER - a task specific noun indicating what aspect of the component it is that is affected by the verb - "POSITION"

STATE - an adjective, noun or adverb which identifies the value of the parameter. The adjective, noun or adverb may be generic or specific - "IN"

OTHER OBJ - a task specific noun which is also (incidentally) affected by the verb. n this instance the value is "null".

SYSTEM - a label for the system involved in the task. This label will found in procedures, on annunciators, on the controls, etc. and is NPP specific depending on the engineering and control room design - "CEDMCS"

INPO - a cross reference to a table for the system s used in the taxonomy developed by the Institute of Nuclear Power Operations - "001"

MEANS - how does the operator in JOBCAT bring the PARAMETER of the COMPONENT in SYSTEM to its required STATE by the action described by VERB? - "CONTINUOUSLY VARIABLE CONTROL"

In this case, as the RO-1 performs the VERB he also communicates with the senior reactor operator (SRO-1) in the control room (CR), so we also have:

MEANS - "VERBAL"

RESPOND - to whom the verbal communication is directed - "SRO - 1"

RLOC - where is the respondent to whom the communication is directed? - "CR"

CONTENT - what is it that RO-1 says to SRO-1? - "REACTOR POWER IS AT 101%"

In this task analysis the accuracy and reliability with which a task can be analyzed will clearly be dependent on the choice of labels for the columns in the TDF, and on the words chosen to fill in entries in columns. During preparations for the TA, decisions must be made in order to make the analysis valid, reliable and cost effective.

1. Prepare a complete list of LOCATIONS. This can be done from photographs and architects' and designers' drawings of the control room. In each case, the location must be verified in the actual control room (not simulator).

2. Prepare a complete list of all system specific and task specific nouns, adjectives and adverbs. This can be done from procedures, photographs, drawings, and procedures, supplemented by questionnaires and interviews with SMEs at the job analysis stage. Every effort should be made to make it complete before the task analysis begins. If extra words must be added later, care must be taken to ensure that all task analysts are informed, and that the computer data base manager is informed. It is important to review the list to ensure that all analysts understand the reference of each term, and that they agree with SMEs, and that the latter agree among themselves.

3. Choose an action verb taxonomy. This can be treated as generic, since the verbs describe what the operator does. Table 3.2.5.T3 is an example from NUREG/CR-3700. It is a modified version of the "Berliner Taxonomy", which has been widely accepted in the nuclear human factors community in the United States. It is recommended that it should be used as a basis for CANDU task analysis, with the following CAUTION: This taxonomy as it stands is deficient for application to "advanced" control rooms (e.g. Darlington). See Section 4.5 below.

Note that while most of the "specific behaviours" (what we have called ACTION verbs) refer to observable behaviour, some do not. An observer can readily decide whether an operator "moves", "discards", or "directs" as those verbs are defined in the taxonomy. But it is not possible to say with certainty whether or not an operator "monitors", "remembers", or "plans".

On this point the distinction between prescriptive task analysis (PTA) and descriptive task analysis (DTA) is crucial. The example TDF in Table 3.2.5.T2 comes from a DTA. In a DTA identifying the action depends on observing the behaviour. In a PTA such is not the case. In a PTA the task analysis begins from a definition of the task and proceeds to a description of how it must, of logical or empirical necessity, be done. For example, if the operator must read a meter on one side of the control room and compare its value with that displayed on another meter at the other side of the control room, and if he neither writes down the first value nor communicates it to a colleague, then "remembers" must be an action or behaviour involved.

If he is required to make a decision or act on the difference between two variables, and only the values of the variables, not their difference, is directly displayed, then "compares" is a behaviour which must occur.

The difference can be summarized in this way. In a DTA the occurrence of an ACTION is a matter of observation. In a PTA it is a matter of prescriptive necessity.

PROCESSES	ACTIVITIES	SPECIFIC BEHAVIORS	DEFINITIONS
1. Perceptual	1.1 Searching for and Receiving Information	1.1.1 Inspects	To examine carefully, or to view closely with critical appraisal.
		1.1.2 Observes	To attend visually to the presence or current status of an object, indication, or event.
		1.1.3 Reads	To examine visually information that is presented symbolically.
		1.1.4 Monitors	To keep track of overtime.
		1.1.5 Scans	To quickly examine displays or other information sources to obtain a general impression.
		1.1.6 Detects	To become aware of the presence or absence of a physical stimulus.
	1.2 Identifying Objects, Actions, Events	1.2.1 Identifies	To recognize the nature of an object or indication according to implicit or predetermined characteristics.
		1.2.2 Locates	To seek out and determine the site or place of an object.
2. Cognitive	2.1 Information Processing	2.1.1 Interpolates	To determine or estimate intermediate values from two given values.
		2.1.2 Verifies	To confirm.
		2.1.3 Remembers	To retain information (short-term memory) or to recall information (long-term memory) for consideration.
	2.2 Problem Solving and Decision Making	2.2.1 Calculates	To determine by mathematical processes.
		2.2.2 Chooses	To select after consideration of alternatives.
		2.2.3 Compares	To examine the characteristics or qualities of two or more objects or concepts for the purpose of discovering similarities or differences.
		2.2.4 Plans	To devise or formulate a program of future or contingent activity.
		2.2.5 Decides	To come to a conclusion based on available information.
		2.2.6 Diagnoses	To recognize or determine the nature or cause of a condition by consideration of signs or symptoms or by the execution of appropriate tests.
3. Motor	3.1 Simple/Discrete	3.1.1 Moves	To change the location of an object.
		3.1.2 Holds	To apply continuous pressure to a control.
		3.1.3 Pushes/Pulls	To exert force away from/toward the actor's body.
		3.1.4 Attaches	To affix an object to a larger object by tying or gluing.
		3.1.5 Gives	To put an object into the possession of another for his use.
		3.1.6 Removes	To detach and move out of position.
		3.1.7 Discards	To get rid of an unnecessary or useless object.
	3.2 Complex/Continuous	3.2.1 Positions	To operate a control that has discrete states.
		3.2.2 Adjusts	To operate a continuous control
		3.2.3 Types	To operate a keyboard.
		3.2.4 Installs	To put into an appointed place or position.
4. Communication		4.0.1 Answers	To respond to a request for information.
		4.0.2 Informs	To impart information.
		4.0.3 Requests	To ask for information.
		4.0.4 Records	To document something, as in writing.
		4.0.5 Directs	To ask for action.
		4.0.6 Receives	To be given written or verbal information
		4.0.7 Returns	To give an object back to its owner.

Action Verbs at the level of Task Elements
based on the Berliner Taxonomy.
(From NUREG/CR-3371)

Table 3.2.5.T3

It follows that validating a DTA taxonomy or method may be difficult. It depends upon the analysts' ability to design measurement, recording and observational techniques. Validating a PTA is a matter or ensuring that the analyst has correctly deduced from procedures, photographs, engineering documents, etc., what must logically be done by the operator to carry out the task.

The choice of a Task Data Form is more complicated. The number of columns is determined by the level of detail required. But it is also determined by considerations of analysis, and the way in which data are going to be transcribed for use in the data base. Furthermore, in a DTA there is a need to be able to transcribe -- and perhaps to record manually -- real time data, and the amount of detail which can be included is reduced. In a PTA there is no such limitation. Table 3.2.5.T4 shows an example of a TDF from DOE/EP-0095 as used during a PTA. Compare it with 3.2.5.T2. Note that the step no. occurs twice, first in a summary list, in which the subtasks are listed as components of the task, and secondarily as a subtask heading in which elements are listed as components of the subtask. At the latter level the coding taxonomy which allows the data to be entered into the data base also appears. Note also that at the sub-task level the verbal description in Element 19 of the TDF is a "narrative" version of a complete line in 3.2.5.T2. At the level at which the taxonomic category is listed, the skills and knowledge required are listed -- information which does not appear in the DTA of 3.2.5.T2, but is clearly of great importance in relating operator training and qualification to control room design and the probability of error or satisfactory performance.

3.2.6 Recommended Task Data Form

In order to combine the fine detail available in the DOE/EP-0095 TDF with the simplicity of use of the NUREG/CR-3371 TDF, we propose the adoption of the TDF shown in Table 3.2.6.T1. It should be printed in such a way that it can be folded along the line indicated, and bound in such a way that it can be kept open either with the sheets fully open or with the right side of the sheet folded back. If used in a tabletop mode of analysis, or for final quality control checks or data base composition it should be used fully open. If used in a "hand held" way for field recording in control room or simulator, it should be used folded into half size.

As will be described in a later chapter, there are three stages at which data will be entered on the form during the Table Top, Walk Through/Talk Through, and Simulator phases. It is desirable to indicate the source of each entry by using different colours. After all three stages have been carried out all cells in the TDF should be full, and data base entry can begin. The form as provided can accommodate all stages.

TASK ANALYSIS DATA COLLECTION FORM

00	0 1 0 1 0 1 0 1 0 0 0 0 1 MIX THE CONTENTS OF THE POISON WATER TANK
01	PARENT TASK ___ ' _____ ' __
02	OUTPUT 01 Poison water tank cadmium nitrate solution has been circulated for 1 hour
03	GENERAL CONDITIONS 01 Plant mode(s) = ALL MODES
04	INITIATING CUE(S) 01 When requested by the routine maintenance schedule
05	TERMINATING CUE(S) 01 Poison water tank has been mixed for 1 hour
06	STANDARDS 01 Poison water tank circulating pump must be run for 1 hour 02 Poison water tank level must be at requested operating level
07	SPECIAL SAFETY CONSIDERATIONS 01 Radiation exposure 02 Personel hazard due to chemical spill - most probable cause of spill is leakage through pump shaft seal
08	CONSEQUENCES OF INADEQUATE PERFORMANCE 01 Possible loss of poison water tank contents

Completed Task Data Form for Prescriptive Task Analysis. (From DOE/EP-0095)

(Table 3.2.5.T4)

TASK ANALYSIS DATA COLLECTION FORM

TASK # Φ18 Φ1

09	SYSTEM INTERFACES	Φ1 AC electrical distribution system
10	HUMAN INTERFACES	Φ1 Shift supervisor
11	GENERAL TOOLS AND EQUIPMENT	NONE
12	GENERAL REFERENCES	Φ1 Poison water solution system operating procedure Φ2 Administrative procedures
13	INSTRUCTIONAL SETTING	Φ1 Optimal – in-plant Φ2 Alternate – classroom
14	JPM METHOD	Φ1 Optimal setting – in-plant Φ2 Optimal method – actual performance Φ3 Alternate setting – classroom Φ4 Alternate method – talk through

15 REVIEW DATA (additional comments can be added on back of sheet with appropriate block number)

REVIEW STEP	NAME(S)	DATE	COMMENTS*	REVIEW STEP	NAME(S)	DATE	COMMENTS*	REVIEW STEP	NAME(S)	DATE	COMMENTS*
1. ORIGINAL TA COMPLETE	Houk / Tache	7/23/92	Poison water Solution SOP	3. VALIDATION CHECK COMPLETE	Bergeron	7/23/92		5. DATA ENTRY COMPLETE	Selawsk	9/9/92	
2. INITIAL OC CHECK COMPLETE	D'Arrigo	7/24/92		4. TAXONOMY COMPLETE	D'Arrigo	7/23/92					

(continued)

ENGINEERING SYSTEM Reactor Poison Water Solution System.
TASK # 018 01
TASK TITLE MIX THE CONTENTS OF THE POISON WATER TANK

STEP	C	19 ELEMENT	20 CONDITIONS	21 STANDARDS	22 REFERENCES	23 TOOLS/EQUIPMENT
01		Verify the poison water tank water fill connection isolation valve is shut and capped			01 Poison water solution system operating procedure	
02		Verify the poison water tank level is at normal operating level by observing the tank sightglass		02 Poison water tank must be at required operating level	02 Poison water solution system operating procedure	
03		Open the poison water tank circulating pump suction and discharge valves			03 Poison water solution system operating procedure	
04		Plug the poison water tank circulating pump power cord in 440V AC outlet			04 Poison water solution system operating procedure	
05		Monitor the poison water tank circulating pump		05 Poison water tank circulating pump must be run for one hour	05 Poison water solution system operating procedure	
06		Unplug the poison water tank circulating pump	06 After 1 hour has elapsed		06 Poison water solution system operating procedure	
07		Close the poison water tank circulating pump suction and discharge valves			07 Poison water solution system operating procedure	
08		Verify the poison water tank level is at normal level by observing the tank sightglass			08 Poison water solution system operating procedure	
09		Make required log entries			09 Administrative procedure	
10		Inform shift supervisor that mixing of the poison water tank is complete				

(continued)

ENGINEERING SYSTEM REACTOR POISON WATER SOLUTION SYSTEM
TASK # 018 01
TASK TITLE FILL THE CONTENTS OF THE POISON WATER TANK

STEP	24 TAXONOMY CODE	SKILLS AND KNOWLEDGE	25 PROBLEM ASSESSMENT (ID any new tasks)	26 PROBLEM RESOLUTION (ID any new tasks)
Φ1	201801000100	Purpose of the reactor poison water system (provide for emergency reactor shutdown)		
	201822010100	Purpose of the poison water tank fill connection (provide capability to add water to the poison water tank)		
	201822020000	Location of the poison water tank fill connection isolation valve (hidden behind shielding)		
Φ2	201822020100	Location of the poison water tank sight glass		
	201801010100	Required level in the poison water tank		
	201822040000	Interpretation of the poison water tank sight glass (linear scale, graduated in inches)		
	301001080100	Chemical formula for Cadmium Nitrate - $Cd(NO_3)_2$		
	301001080200	Chemical characteristics of Cadmium Nitrate A Readily absorbs neutrons through chemical reaction B Remain in solution at room temperature		
	301001080500	Purpose of Cadmium Nitrate ($Cd(NO_3)_2$) (acts as a poison to ensure emergency reactor shutdown margin)		
	301001040100	Definition of a "poison" (any chemical or ion that has an affinity for absorbing neutrons)		
Φ3	201801020100	Flowpath for circulating the poison water tank		
	201821020100	Location of the poison water tank circulating pump suction valve		
	201821020200	Location of the poison water tank circulating pump discharge valve		
	201810030100	Operation of the poison water tank circulating pump suction valve (manually operated valve)		
	201820030100	Operation of the poison water tank circulating pump discharge valve (manually operated valve)		
	101307050500	Operation of manual hand wheel operated valves (open counter-clockwise, close clockwise)		

(continued)

ENGINEERING SYSTEM REACTOR POISON WATER SOLUTION SYSTEM
TASK # 018 01
TASK TITLE FILL THE CONTENTS OF THE POISON WATER TANK

STEP	24 TAXONOMY CODE	SKILLS AND KNOWLEDGE	25 PROBLEM ASSESSMENT (ID any new tasks)	26 PROBLEM RESOLUTION (ID any new tasks)
Ø4	201821010100	Location of the poison water tank circulating pump power cord		
	201821012020	Location of the poison water tank circulating pump 440V AC electrical cord		
	201821012030	Location of the poison water tank circulating pump electrical outlet supply circuit breaker		
	201821030100	Poison water tank circulating pump power supply		
	206822030200	Effect of circulating the poison water tank on the reliability of poison water for emergency reactor shutdown (possible delay in the initiation of poison water dump could result)		
Ø5	301003010300	Characteristics of chemicals in solution (over time, chemicals tend to precipitate out of solution unless stirred or agitated.)		
	206801020100	Flowpath for circulating the poison water tank		
	201803010000	Reason for circulating the poison water tank for one hour (ensure even mixing of the poison throughout the solution, prevent stratification)		
	206803030100	Purpose of the poison water circulating pump (circulates Sodium nitrate solution through the poison water tank to ensure even mixing of the solution)		
Ø6	201821010100	Location of the poison water tank circulating pump power cord		
	206821020200	Location of the poison water tank circulating pump 440V AC electrical outlet		
	206821020300	Location of the poison water tank circulating pump electrical outlet supply circuit breaker		
	206821030100	Poison water tank circulating pump power supply		
Ø7	206807020100	Flowpath for circulating the poison water tank		
	206820010100	Location of the poison water tank circulating pump suction valve		
	206820012100	Location of the poison water tank circulating pump discharge valve		
	206821030100	Operation of the poison water tank circulating pump suction valve (manually operated valve)		
	206820030200	Operation of the poison water tank circulating pump discharge valve (manually operated valve)		
	012307030300	Operation of manual mechanical operated valves (open counter-clockwise, close clockwise)		

(continued)

ENGINEERING SYSTEM REACTOR POISON WATER SOLUTION
TASK # A1B 01
TASK TITLE FILL THE CONTENTS OF THE POISON WATER TANK

STEP	24 TAXONOMY CODE	SKILLS AND KNOWLEDGE	25 PROBLEM ASSESSMENT (ID any new tasks)	26 PROBLEM RESOLUTION (ID any new tasks)
Φ8	2018220201000	Location of the poison water tank sightglass		
	2018040101000	Required level in the poison water tank		
	2018220101000	Interpretation of the poison water tank sightglass (linear scale, graduated in inches)		
	3010040800200	Chemical characteristics of cadmium nitrate A Readily absorbs neutrons through chemical reaction B Remains in solution at room temperature		
	3010040800300	Purpose of cadmium nitrate ($Cd(NO_3)_2$) (acts as a poison to ensure adequate reactor shut down margin)		
	3010001040100	Definition of a "poison" (any chemical or ion that has an affinity for absorbing neutrons)		
	3010040800100	Chemical formula for cadmium nitrate - $Cd(NO_3)_2$		
Φ9	2030202030100	Location of control room log		
	2030101060200	Familiarity with administrative procedures regarding log entries		
	3011030401800	Ability to make proper log entries (clear, concise, legible)		
1Φ	3013070300100	Communications skill (face-to-face passing information)		

(continued)

Table 3.2.6.T1
TASK ANALYSIS DATA FORM: IDENTIFICATION DATA

1. UTILITY ID

2. PLANT ID

3. REACTOR ID

4. ARCHITECT ENGINEERS
(a) (b) (c)

5. DESIGN ENGINEERS
(a) (b) (c)

6. PROCEDURE WRITERS
(a) (b) (c)

7. CONTROL ROOM DESIGNERS
(a) (b) (c)

8. SOFTWARE DESIGNERS
(a) (b) (c)

9. TASK ANALYSIS
(a) (b) (c)

10. DATA BASE

11. DATA BASE PERSONNEL
(a) (b) (c)

12. QUALITY ASSURANCE
(a) (b) (c)

13. OPERATORS
(a) (b) (c)

14. MANAGEMENT
(a) (b) (c)

15. TRAINING STAFF
(a) (b) (c)

16. MAINTENANCE STAFF
(a) (b) (c)

20. TASK DEFINITION

21. TASK PURPOSE

22. TASK DURATION

23. TASK SEQUENCE NO.

24. PROCEDURE REFERENCE

25. INPO TASK CODE

100. END RESULT OF TASK: SYSTEM FINAL STATE

101. INITIATING CUE

102. TERMINATING CUE

103. REFERENCE STANDARDS

104. SPECIAL SAFETY CONSIDERATIONS AND HAZARDS

105. CONSEQUENCES OF INADEQUATE PERFORMANCE

106. "GENERAL LOCATION: SYSTEM INTERFACE

107. PERSONNEL INVOLVED

200. TYPE OF TA TABLETOP WALKTHROUGH/TALKTHROUGH
SIMULATOR COMBINATION TT/WTTT ALL

201. QUALITY CONTROL COMPLETED

202. QUALITY CHECK PERFORMED BY

203. TAXONOMIC CODING PERFORMED BY

204. TAXONOMIC CODING CHECKED BY

Notes: 25. Although INPO codes will not in general be suitable, use where possible will facilitate generality and data exchange.
(a) (b) (c) entries should give names or IDs of personnel who contribute to the TA and who may need to be contacted to clarify data.

TABLE 3.2.6.T1
cont'd -- TASK ANALYSIS DATA FORM: TASK ELEMENT ANALYSIS

300 WHO TAKES ACTION	301 LOCATION	302 TIME	303 VERB	304 COMPONENT	305 PARAMETER	306 STATE	307 OTHER OBJECT	308 PLANT SYSTEM	309 MEANS OF ACTION	310 FROM	COMMUNICATION 311 TO	COMMUNICATION 312 HOW	313 CONTENT

Fold Here:

Notes: This page should be used to record data during the TT, WTIT, or simulator stages.

TABLE 3.2.6.T1
cont'd TASK ANALYSIS DATA FORM: TASK ELEMENT ANALYSIS

314 SKILL REQ'D	315 KNOW-LEDGE REQ'D	316 TOOLS, EQUIP.	317 CONNECT. WITH OTHER TASK	318 CONNECT. WITH OTHER OPER.	319 COMMENTS	320 EST. p (ERROR)	321 TAXO-NOMIC CODE

Fold Here:

Notes: This page should be used during the post data collection analysis phase in which the implications of the left hand page are developed.

320. If possible probabilities of errors can be entered here based on references in the literature to error probabilities associated with the action verbs, skills and knowledge entries in 303 304, 309, 310, 311, 312, 314 and 315.

321. This is the code which will be entered into the computer. Note that combining all the entries produces 61 entries. Even a single row on this page produces 21 values to be coded, several of which may have multiple values rather than binary values. The design of an efficient code is a highly sophisticated task.

4.0 THE CONDUCT OF TASK ANALYSIS

This chapter describes the stages involved in a prescriptive task analysis. The stages which will be listed in 4.1 and described more thoroughly in sections 4.2 and 4.4 will be needed regardless of which the TDF is chosen. Even in a descriptive task analysis the three main stages should be used.

This chapter assumes that a complete listing of tasks has been completed during the job analysis phase of the investigation (see Section 3.2.3), and that a subset of tasks has been selected for PTA taking costs and benefits into account.

4.1 Summary of Stages

Assuming that the complete list of tasks is available at the end of the job analysis, and that a choice has been made as to a particular task to be analyzed, there are three main steps of a task analysis: Table Top Analysis (TT), Walk Through/Talk Through Analysis (WTTT), and Simulator Analysis. Of these the first two should be regarded as mandatory in all TAs, and when a simulator is available the third should also be regarded as mandatory.

In addition there are four supporting activities, namely three quality control and +reliability checks, and "Paradigming". The quality control stages are mandatory. "Paradigming" is required if the TA reveals that there are deficiencies in the operating procedures. In each of the following stages at least some steps should be carried out by two task analysts independently for the purpose of quality control and reliability checks.

4.2 Description of Stages

4.2.1 Table Top Task Analysis (TT)

The task analyst begins by going step by step through the operating procedures which refer to the selected task. If a task has been identified for which no procedures exist, SME's and design engineers should be consulted, and a procedure developed. This may be done either by "paradigming" (see Section 4.2.4) or by considering the properties of the engineered systems in the way it was done when the existing procedures were written. Each line in TDF is filled for one element, column by column. Ambiguities and omissions are noted. When the entries are as complete as possible SMEs are taken through the procedures and asked to state whether the elements of the task are correct and are carried out as described.

Between these two stages questionnaires are prepared to guide the discussion of ambiguities and omissions. If a SME reveals that practice differs from the written procedures, describes an extra element, or omits an element, then detailed questioning is used to clarify the situation.

It is at this stage also that it is important for the task analysts to go behind the operating procedures to the engineering design manuals to establish what view the engineers had of the properties of the system and the range of functions which they intended operators to control. It is usual for the design of the control room and the operating procedure to be developed in relation to each other. Hence neither can be used to check the quality of the other. If there are controls or displays to which no

procedure refers this cannot be established merely from the procedures. If there is a task which has never been performed, which may one day be required, but for which no procedure has been written, this cannot be discovered by examining the procedures or the control room. But if the engineering design manuals are examined carefully, they should reveal such deficiencies at least in some cases, since they may describe functions to be performed by the hardware, including engineered safety systems, for which no procedure has been written, or with respect to which the existing operating procedures seem to be in error.

Neither DOE/EP-0095, NUREG-0700, nor INPO-83-046 recommend this procedure, but the need for it is logically compelling if it is desired to discover cases where procedures have been omitted. Where procedures exist and are in frequent use their established success is enough to establish that they are sufficient for their purpose. To decide whether they are necessary for their purpose (or whether, for example, there there may be a better procedure) the method recommended here is required. Where equipment and procedures for its use both exist and are in frequent use, there is least need for it. But if it is desired to check that all equipment has a correct procedure for its use, and all procedures correctly use equipment the method must be invoked. At the very least the TA should make explicit whether or not the procedures have been checked against engineering design specifications.

The method recommended constitutes "defense in depth" of the quality of the task analysis.

After the interviewing and questionnaires are completed, the TDF should be updated, and at the end of that operation, reliability and quality control tests should be applied. An example of a quality control check list from NUREG/CR-3700 is shown in Table 4.2.1.T1. A senior experienced task analyst should examine the TDF to ensure that only standard vocabulary has been used, that the columns of the TDF have been properly used, and that all entries are unambiguous. In cases where two analysts have examined an identical subtask or elements, the entries in the TDF should be compared to ensure that the entries are identical. If discrepancies, ambiguities or errors are discovered they must be resolved or corrected by a reiterative passage through the procedures, SME interviews and tests. If gaps are found "paradigming" must be performed. (See 4.2.4 below)

4.2.2 Walk-Through/Talk-Through Analysis (WTTT)

This method is halfway between table-top and full scale realistic testing of the operator. An experienced operator or team of operators is taken either to a high fidelity simulator or the actual control room, and "walked through" the task. The operator walks about the control room or simulator as if he were performing the task but without actually performing the action. As he does so the operator gives a running commentary on what he is doing, "I am now moving to have a look at the temperature of the cold leg input ..... I would next activate this switch in order to start the No. 2 high pressure injection pump .... " and so on.

Quality Control Checklist - Final

Plant Identification

1. All Plant Identification entries are completed.
2. Plant name is consistent with Data Review Check Sheet.

Task Identification

3. All Task Identification entries are completed.
4. Operating Sequence is consistent with Data Review Check Sheet.
5. All task statements are written in imperative, active form.
6. All task purposes begin with the word "to."
7. Task Duration is written to indicate time.

Description of Task Action

8. All Description of Task Action entries are from the list of acceptable entries (Figure A-7) for the following fields:

   JOBCAT
   COMPONENT
   MEANS
   RLOC
   VERB
   PARAMETER
   RESPOND
   STATE

9. Start and stop times for each behavioral element are indicated.
10. All element VERB entries are written in third person, active, singular.
11. All LOC entries are consistent with the plant-specific plan view drawing.
12. When a Communication Link field is used, there are no entries in the Object of Action fields.
13. When an Object of Action field is used, there are no entries in the Communication Link fields.
14. When component and/or parameter entries are made, there must be an entry for the appropriate system.
15. When the OTHER OBJECT field is used, it is the only field used under Object of Action.
16. All Plant System entries are from the systems list for the specific plant.
17. All INPO EQUIV entries match the plant system list entries, as given in the translation list.
18. When COMMUNICATION LINK field is used, there is an entry in CONTENT field.

Organization

19. All Task Data Forms have the same Plant name and Operating Sequence entries.
20. All Task Data Forms are arranged in the proper sequence.

Quality Control Checklist
(From NUREG/CR-3371)

Table 4.2.1.T1

During this process a videotape recording should be made of everything that happens, if necessary with more than one camera. An audio recording should be made, either on the videotape or with a separate recorder. In addition the task analyst should take paper and pencil notes and fill in data for the TDF. The best way would be to use a new TDF sheet onto which data from the TT task analysis had been copied. Entries during the WTTT should be made in a colour different from the TT stage. At any moment when the task analyst detects ambiguity or some behaviour or speech which is unintelligible, the task analyst should stop the WTTT and ask the operators to clarify the situation.

After the task is finished, TDF is examined for discrepancies between the TT and WTTT methods. Where such discrepancies are found, the video and audio records are examined, and if necessary further interviews conducted with SMEs. Finally the video and audio records should be examined carefully and further details added to the TDF. If required "paradigming" should be performed. Quality assurance and reliability tests should again be carried out.

CAUTION: If the WTTT is performed in the real control room great care should be taken that no actions are inadvertently carried out. Since the operator may be carrying out a task with which he is very familiar, there will be a tendency for the scenario to trigger semiautomatic responses. If the operator is describing a sequence and "miming" the actions, they may actually be carried to completion. One member of the team must monitor the operator to prevent such inadvertent actions.

4.2.3 Simulator Analysis

The final source of data is a full scale simulation of the task. The operator performs the task embedded in a scenario on a high fidelity simulator, without interruption and in real time. Video and audio recording should be used, and pencil and paper recording. The analysis of the recorded data proceeds as in WTTT, and the use of paradigming, interviews, quality assurance and reliability proceeds as before. All high fidelity training simulators should be provided with performance monitoring systems and the data from the PMS should also be collected and analyzed as needed.

It is most important to bear in mind that if the simulator is not an exact replica of the control room both structurally and functionally there may be discrepancies between what is recorded at this stage compared with what has been found in TT and WTTT stages. It is important to resolve such discrepancies, and be certain which behaviour is typical of the real control room. It is common in many industries to find that modifications to the real plant are not always carried through as modifications to simulator hardware and software. Moreover there may be cases where the simulator dynamics do not exactly model the real process. Again discrepancies should be noted and resolved.

4.2.4 "Paradigming"

The is the name given by DOE/EP-0095 to the process used when a task, sub-task, or element is discovered for which no procedure exists due to an oversight during the procedure development process or due to event complexity. In the former situation, operators may have invented sequences of actions which deal with the situation to the best of their abilities. In the latter situation, operators will respond with strategies for corrective actions learned during training and based on treating the symptoms of safety functions (i.e., reactor power control, core cooling, and radioactivity

containment). What is required is a systematic method to work from a sequence of behaviour for which no written procedure exists, to a formal procedure which is sufficient to guarantee safety and efficient performance. Paradigming is a way of constructing a procedure from a DTA, since in the absence of a procedure there can be no PTA for that task, subtask or element. The only TA method to discuss this problem is DOE/EP-0095. It is recommended that the approach described in DOE/EP-0095 be

4.3 Data Base Design

The full usefulness of a task analysis depends on the flexibility and ease with which the data can be examined. It should be possible for the analyst or the client to ask a wide variety of questions, to compare different tasks and elements, to examine the data to establish the types of cognitive information processing required, to compare one task analysis with another, and even to compare and combine data from TAs done on different plants to enrich the data base and improve its reliability.

Given the enormous quantity and complexity of the data, the only way in which it can be used is by a well organized computerized data base management program. It is not possible in this document to go in detail into the choice and design of a suitable system. DOE/EP-0095 provides an introduction to the taxonomic aspects of a data base. NUREG/CR-3606 provides a detailed account of the SEEK data base associated with the task analysis performed by Burgy et al. (NUREG/CR-3371). Examples of a typical printout of the latter, of the INPO task analysis data base and of the NUREG data base are provided in Tables 4.3.T1, 4.3.T2 and 4.3.T3.

No existing data base management program can be used as it stands for CANDU TAs, because of differences in vocabulary, taxonomy, system hardware and TA method. The most important characteristic is that questions can be asked of the database which were not foreseen at the time it was constructed. Anecdotal accounts suggest that neither SEEK nor the INPO data base is entirely successful in this respect, but the INPO one is the more interesting because it is derived from a PTA while SEEK is derived only from a DTA.

Every effort should be made by the AECB to encourage Canadian utilities to develop a common data base management system for CANDU task analyses. Data base design and management calls for a high level of professional expertise, and is expensive. It will be far more cost effective if a single system can be developed of which the cost can be amortized over several task analyses. Recent developments in data transmission strongly argue for a network to be shared by utilities and connected on-line to the NPPs as TAs are carried out at different sites. Data will be entered by the appropriate member of the task analysis team on site through a terminal. Provision must be made in the software for checking data entries. The known error rates of keypunching are sufficiently high that in entering data from a large TA there will be several hundred errors. Many of these will be self corrected, but every effort must be made to catch the remainder, particularly with regard to taxonomic codes, which usually have no redundancy. The number of data fields is very large, and the taxonomic codes therefore long. It will almost certainly be worth building some error detecting codes into the taxonomic codes, so that an incorrect keystroke will often give an inadmissable entry rather than an incorrect one.

```
                    NRC DATABASE RETRIEVAL PROGRAM

SEEK: PLANT=15 AND OPSEQID=25

7 HITS
SEEK: .D

Do you want to see all fields in the record? (Y/N) N

Enter the names of the fields you want listed:
> ?

The following fields have been established for this data file
============================================================

ID              PLANT           UNIT            NSSSVEND
AE              TQVEND          CRTYPE          DLDATE
OPSEQ           OPSEQID         OPFUNC          OPSFUNC
COMM            CUE             TSKSTMT         TSKPUR
TSKCODE         TSKSEQNO        TSKDUR          PROC
DATACOLAT       JOBCAT          LOC             TIME
VERB            COMP            PAR             STATE
OTOBJ           SYS             EQUIV           MEANS
RESP            RLOC            CONTENT         RTS
INDIFF          INPORT          PLANDIFF        PLANPORT
TIMCRIT         INPOCOMP        PLANCOMP
You may enter:
  The fields or report formats you want seperated by
  commas or spaces.  Stored report formats may be
  used by entering a $ followed by the report name.
  S ---- To return to SEEK
  Q ---- To QUIT the program
  ? ---- To get this message
Do you want to see all fields in the record? (Y/N) N

Enter the names of the fields you want listed:
> ID PLANT TSKSTMT OPSEQ

TASK DATA FORM (DESCRIPTIVE) DISPLAY PROGRAM
HIT. . . . . 1
ID . . . . . 15-25-01
PLANT #. . . . . 15
TASK STATEMENT. . . . . RESPOND TO RETENTION BASIN TROUBLE ALARM
OPERATING SEQUENCE. . RADWASTE DISCHARGE

HIT. . . . . 2
ID . . . . . 15-25-04
PLANT #. . . . . 15
TASK STATEMENT. . . . . NOTIFY SHIFT SUPERVISOR
OPERATING SEQUENCE. . RADWASTE DISCHARGE

HIT. . . . . 3
ID . . . . . 15-25-02
PLANT # . . . . . 15
TASK STATEMENT . . . . . DIRECT PLANT EQUIPMENT OPERATOR TO TERMINATE RELEASE
OPERATING SEQUENCE. . RADWASTE DISCHARGE

Option? (NL, Hn, D, DP, S, Q, ?) Q
```

Example of Database Access
(From NUREG/CR-3606)

Table 4.3.T1

```
                                NRC DATABASE RETRIEVAL PROGRAM

SEEK> PLANT=39 AND OPSEQID=13 AND SAVE=NRC 1

726 HITS
SEEK> .SORT

ENTER -P- FOR PRINTER OR -T- FOR TERMINAL> T

ENTER THE ATTRIBUTES TO SORT BY (ONE-AT-A-TIME):

ATTRIBUTE NO. 1: JOBCAT

DO YOU WANT TO EXPLODE JOBCAT? N

ATTRIBUTE NO. 2: TIME

DO YOU WANT TO EXPLODE TIME? N

ATTRIBUTE NO. 3:

Processing data.
W O R K I N G

726 records selected.

Saved list "&TEMP27&" in file "&SAVEDLISTS&".

726 records selected.
D O N E   W O R K I N G
Do you want to see all fields in the record? (Y/N) N

Enter the names of the fields you want listed:
> JOBCAT TIME LOC VERB COMP PAR STATE SYS MEANS TSKSEQNO

TASK DATA FORM (DESCRIPTIVE) DISPLAY PROGRAM
HIT . . . . . 1
JOB CATEGORY. . . . . RO-1
TIME. . . . . 00 00:40-00:00:44
LOCATION. . . . . 39V
VERB . . . . . OBSERVES
COMPONENT. . . . . HEAT EXCHANGER (RHX)
PARAMETER. . . . . FLOW
STATE . . . . . ABOVE LIMIT
PLANT SYSTEM. . . . . CVCS
MEANS . . . . . ANNUNCIATOR
TASK SEQUENCE NO. . . 01

Option? (NL, Hn, D, DP, S, Q, ?) S

SEEK>
```

Example of sorting by Job Category and Time. (From NUREG/CR-3606)

Table 4.3.T2

```
        NRC CREW TASK DATABASE DISPLAY PROGRAMS                10:12:06 08 APR 1984

 1= To SEEK on NRC records.
 2= To Generate TASK DATA FORM Output
 3= To display NRC cross reference items
 4= To logoff the system

Which would you like? ( 1 - 4 )=3

 Enter one of the following categories
   JOBCAT  VERB     COMPONENT     PARAMETER
   STATE   MEANS    RESP          RLOC
Enter Category =JOBCAT

Enter Newline or LPTR =

SORT RF/JOBCAT    10.12:19  04-08-84  PAGE       1
JOBCAT.....................  TEXT.............................

ERROR                        ERROR OR UNKNOWN
RO-1
RO-2
RO-3
SM                           STATION (PLANT) MANAGER
SRO-1
SRO-2                        SHIFT SUPERVISOR
SS                           SHIFT SUPERINTENDENT
STA                          SHIFT TECHNICAL ADVISOR

9 records listed
(Press <NEW LINE> to continue) . . . =

        NRC CREW TASK DATABASE DISPLAY PROGRAMS                10:12:23 08 APR 1984

 1= To SEEK on NRC records.
 2= To Generate TASK DATA FORM Output
 3= To display NRC cross reference items
 4= To logoff the system

Which would you like? ( 1 - 4 )=1

SEEK> PLANT=98 AND OPSEQID=08 AND SAVE=NRC 1

182 HITS
SEEK> AND JOBCAT=RO-1
55 HITS
SEEK>  UNABRIDGE

SYNONYM ON
XF SYNONYM ON
SEEK> AND VERB=MOTOR

ADDING VERB XF SYNONYM FOR MOTOR = ADJUSTS
ADDING VERB XF SYNONYM FOR MOTOR = ATTACHES
ADDING VERB XF SYNONYM FOR MOTOR = DISCARDS
ADDING VERB XF SYNONYM FOR MOTOR = GIVES
ADDING VERB XF SYNONYM FOR MOTOR = HOLDS
ADDING VERB XF SYNONYM FOR MOTOR = INSTALLS
ADDING VERB XF SYNONYM FOR MOTOR = MOVES
ADDING VERB XF SYNONYM FOR MOTOR = POSITIONS
ADDING VERB XF SYNONYM FOR MOTOR = PULLS
ADDING VERB XF SYNONYM FOR MOTOR = PUSHES
ADDING VERB XF SYNONYM FOR MOTOR = REMOVES
ADDING VERB XF SYNONYM FOR MOTOR = TYPES
6 HITS
SEEK>
```

Example of Database Access.
(From NUREG/CR-3606)

Table 4.3.T3

The data base will require at least the 61 data fields included in the recommended Task Data Form, and entries in most of the fields will be multivalued if numerical and may contain extended strings in the comment field.

The design of an appropriate data base should be the subject of a separate contract and should involve cooperation with utilities.

4.4 Application to "Event Based" or "Symptom Based" Emergency Procedures

The method of task analysis to be proposed is applicable equally to "Event based", Symptom based" or indeed any other kind of emergency operating procedures. The difference between different approaches to emergency procedures, (or to any other tasks) will appear as differences in the nouns and action verbs which appear in the TDFs. In particular, the nouns will be different. In one method one will find that an operator "monitors" several individual instruments, then "compares", "thinks" and "decides" that the plant is in a particular condition requiring a particular action. In another method he "notices" that "loss of coolant" indicator is "abnormal" and takes the same action. The task analysis method is not different, although the linguistic content of the data may well be.

4.5 Problems with "Advanced" Control Room Task Analysis

4.5.1 Definition of "Advanced" Control Room

By "advanced" we mean a control room in which the presentation of information is predominantly by means of computer graphic displays and control is exercised through the intermediary of a computer: often the NPP itself is automatically controlled. It appears that at the time of writing no complete task analysis of an "advanced" NPP control room has been performed in Canada or the U.S. The most likely source of an example would be one of the European stations, particularly the Halden simulator.

Three problems are likely to be encountered, and while the method of task analysis described herein should be adequate to analyze such control rooms, the AECB and the utilities should consider these problems carefully, since they do have regulatory implications.

4.5.2 The Problem of Supervisory Control

The role of the operator in a highly automatic plant is largely supervisory. For long periods, including even much of the time during an emergency when the automatic safety systems are operating, the operator will appear to be doing nothing. At best he will be calling data up for display on the computer driven screens. But the "monitoring", "scanning", "comparing", "deciding", etc. will take place with a minimum of movement as he sits in front of an array of CRTs instead of moving around a conventional control room.

The only source of data for a DTA will be the keystrokes (or other actions) by which the operator directs and interrogates the computer. In a system with a certain amount of artificial intelligence, so that the computers display to the operator the information most probably required, (such as an advanced SPDS or similar) virtually no overt behaviour will be observed. In such cases, if a DTA is required, it will be necessary

to record and analyze eye movements, and combine such a record with WTTT data. Even then the data will be difficult to interpret.

The remarks made elsewhere about PTA for cognitive (i.e. information processing) tasks apply here with even more force. The PTA will derive from the procedures by logical deduction the sequence of information processing activities which are logically implied as necessary by these procedures. No behavioural recording is needed unless a DTA is desired. But special care will have to be taken in the PTA, since without eye movements there will be no check on ambiguous or omitted steps, and little opportunity for paradigming will occur. In particular the prediction of operator overload, error rates, etc. will require great care in relating the logically deduced operations to what is known about the rates at which such operations can be performed by humans, and the rates at which errors occur in cognitive tasks. CAUTION: very few data exist as of 1985 about the degree to which computer displays alter, if at all, human information processing methods, tactics, rates, and error probabilities. To admit that fact does not cast doubt on the ability of the TA method herein described to deliver good TA data: it casts doubt on the ability of any TA method to deliver good data.

4.5.3 Lack of Standard Vocabulary

The 'Berliner taxonomy' was developed before the advent of computer driven displays and computer driven controls. Hence there are no action verbs relevant to certain levels of description. Suppose that an operator calls up a display in order to examine it. This seems to be a radically different action from "scanning" or "looking at" or "monitoring" a meter. But should the verb be "calls up", "interrogates", "accesses", "displays", or some other word? If we suppose for the moment that only a keyboard (and not a trackball, joystick, mouse or other input device) is available, then at one level of description the only action taken is "types", or "presses key". But such a description is clearly inadequate.

Furthermore, advancing computer graphics technology both in software and hardware is introducing new options almost monthly. Older "advanced" systems might have required an operator to erase an old display when calling up a new one, because the new display would necessarily overwrite what was on the screen. But new techniques allow the screen to be partitioned, so that a single display which filled the whole screen might be condensed into the upper left quadrant of the screen and three new screens be displayed in the other three quadrants, each being automatically scaled to fit the space. Even more recent is the technique known as "windowing" in which new displays partly overlie early ones, much as sheets of paper on a desk overlie one another. When the top "page" is removed, the old data reappear just as would be the case with a stack of paper.

There is at present no standard vocabulary to describe such events -- certainly not simple single-word verbs. Because of the dynamic state of computer technology we do not feel able to recommend an appropriate list with any feeling of certainty as to its applicability or durability. Some candidates which suggest themselves are "calls up", "retrieves", "windows", "erases", "displays", "overwrites", "saves", "stores", "prints", etc. CAUTION: Before undertaking a TA of an "advanced" control room the TA team and NPP personnel must discuss appropriate vocabulary and define one that is mutually acceptable. This discussion must include definitions which are compatible with any existing information in the data base derived from earlier TAs.

4.5.4 Flexible Procedures for Displaying Information in "Advanced" Control Rooms

A unique property of control rooms containing multiple CRT displays is their flexibility. This will cause difficulties for procedure writers, task analysts, regulators, and, it must be added, operators.

To bring out this point, consider a much simpler system such as an "advanced" ship's engine room with, say, three CRTs used to monitor and control two engines. Because the displays are not hardwired, each screen can be used for multiple purposes, and will, at different times, contain different information. One of the authors of the present document predicted that a new class of operator errors would occur in such systems due to the operator losing track of what information was on which screen. For example, after a sequence of rapid changes of display a screen with data about the starboard engine might be displayed on the operator's port screen. Operators have a very strong tendency to associate the position of displays with the position of controls. As a result it is easy for an operator, having displayed information from a starboard (right hand side) engine on a port (left hand side) screen, to act as though the controls too had been moved, and to use the port controls to try to shut down the starboard engine. One case of a serious error of this kind has already been recorded by the same author.

Consider this effect now scaled up to a multiple screen display in an "advanced" NPP control room. The operating procedures will tell the operator to display, say, the neutron flux of an area of the core. But will he be told on which screen to display it? The procedures will indicate that the operator should examine, say, the temperature, pressure, and flow through a particular valve. But it will probably not be the case that he will be told on which screen to display the variables, since to do so would remove the very flexibility which is held to be a main virtue of "soft" displays. Furthermore, which screen is used for which display will depend on what information is currently being displayed, what has recently been displayed, etc. A particular display will be on the "top" of a windowed stack on one occasion, and on another occasion two "pages" down. On one occasion the operator may erase what is already on the screen with a new display, on another occasion the new display will merely be "windowed" onto the top of the "page stack", or put up into a currently unused quadrant of a "partitioned" screen.

At what level should the task be described? Is it enough that the TDF says "calls up" "valve temperature"; should it say "calls up" "valve temperature" "erasing old screen"; or should it say "calls up" "valve temperature" "on screen 3" "erasing prior display"? The choice will depend on the way in which the procedures are written, which in turn will depend on the regulatory attitude to flexibility.

Notice that again there will be a breakdown of the relation between PTA and DTA of a kind that will not be found in conventional hardwired control rooms. The PTA may call for a group of displays to be called up simultaneously. But on one occasion these might be in a column, on another occasion in a row, and on another occasion randomly distributed over a 4 X 4 array of CRTs. Hence the relation between TT, WTTT and Simulator phases of the TA will be quite different from that found in TAs of conventional control rooms.

Again we maintain that the TA method recommended in the present document will be as adequate as any to deal with the new situation. But there is no doubt that problems will arise.

As a final comment we would suggest that the flexibility of control rooms using a few "soft" displays and controls instead of a large number of hard wired displays and controls has the potential for being a rich source of new kinds of human error for which we have no data. It is for this reason that we use the word "advanced" in quotes throughout this document.

> CAUTION: We strongly recommend research by the AECB or NPP utilities on the human factors and ergonomics of "advanced" control rooms, using conditions which submit operators to stress and rapid decisions. Research is also needed into details of task analysis vocabulary for computer driven systems.

5.0 RELIABILITY, VALIDITY AND VERIFICATION

TA is a method of measurement and classification, even though qualitative. Fundamental to all measurement are two questions. The first is whether the measurements are valid: Is what the method claims to measure actually what is measured? The second is reliability: Do repeated measurements always give the same result, irrespective of who performs them and how often? This section discusses these problems in the context of TA, and examines the various usages of the terms "validation", "verification", and "reliability" as currently applied to NPP task analysis.

5.1 Introduction

In discussing the role of reliability, validity and verification in determining a satisfactory method of task analysis, it is important to clarify in each case whether the terms refer to the task analysis method, or the task analysis results.

For example, INPO-83-046 states that validation determines whether the operating crew can perform their tasks effectively given the controls and instrumentation available in the control room which is analyzed, while verification ensures the technical accuracy and completeness of the information generated during the task analysis, by means of a double check on the accuracy of procedures and accuracy of transcription. These definitions are not appropriate for our purpose, since validation is of the properties of the control room. In this report we are not concerned with that problem. We are concerned with the validation of the task analysis method itself. If fact, what INPO calls verification we here call validity. The DOE document is in this respect more accurate. It defines the validity of a task analysis as the extent to which it actually does what it claims to do -- namely, to give an exhaustive and accurate description of all aspects of the task analyzed.

In this document we therefore adopt the following definitions.

5.2 Validity

The validity of a task analysis method is measured by the extent to which the method actually provides a complete description of the task analyzed. Does the method "deliver the goods"?

The best way of establishing the validity of a task analysis method is by the use of a "calibration task". The task should be designed to be of the same order of complexity as those to which the TA method will be applied. The task should be designed so that there is no doubt as to what detailed information should appear in a successful task analysis. The results of analyzing the calibration task should be a description which contains all the features of the task which were built into it. This description should be so accurate that an untrained operator can carry out the task correctly (albeit slowly).

A more common technique for "validation" is to have the results of a task analysis reviewed by subject matter experts to rate the accuracy of the description. This is an essential step in the use of task analysis, but is more properly seen as a matter of verification for a particular application of a task analysis method, rather than a

validation of the method as such. The term "validation" should be restricted to validating a task analysis method as such: "verification" should refer to a particular application of the method.

5.3 Reliability

The reliability of a task analysis method is measured by the extent to which the content (result) of a task analysis remains the same when a particular task is analyzed by different people using that method, and when a single person analyzes a given task on different occasions. A reliable method of task analysis yields results which are (1) stable over time and (2) independent of the analyst who performs the task analysis. Particularly with regard to the second of these characteristics an implicit assumption is that the analysts are well trained.

Reliability is again best established by constructing an artificial calibration task whose detailed structure is entirely known, and having it analyzed by a series of analysts, and by each analyst on a series of occasions with a considerable lapse of time (at least a month) between the occasions. The calibration task should be of the same order of complexity as tasks to which it is intended to apply the method.

5.4 The Relation of Reliability to Validity

Both validity and reliability are required for an acceptable method. As applied to task analysis the problems are slightly different from their traditional application in psychological testing. A task analysis method which is valid must by definition be reliable, since it will produce an exact and exhaustive description of a task. This description must of necessity be identical on different occasions and when obtained by different people. (In practice, of course, it is unlikely that any method will be completely valid, and hence some unreliability is to be expected.)

On the other hand a method may be completely reliable and at the same time have any degree of validity. For example, a task analysis might inadvertently fail to record the order in which a set of actions is required. The description produced might be highly reliable but invalid, because while they were identical on different occasions and when done by different analysts, in all cases the data on the sequencing of the actions were absent.

Although in theory it should be possible to design a "foolproof" method of task analysis, in practice both validity and reliability will be strongly affected by the training and experience of the analysts. It is the role of "verification" to take this into account.

6.0 GENERIC OUTLINE OF PREPARATIONS FOR TASK ANALYSIS

The reader is urged also to read the relevant sections of DOE/EP-0095.

The purpose of this section is to ensure that all necessary steps are taken prior to beginning to collect TA data. In view of the shortage of experienced human factors practitioners in Canada, it is likely that some of those involved in a TA will be relatively inexperienced. This section is a guide for reducing the effects of inexperience, and to help those commissioning a TA to check on the quality of the work as the TA develops.

6.1 Preparing for a Task Analysis: Training, Reliability, and Validity

6.1.1 Training in TA Skills

i Analysts must know how to design questionnaires:
- avoid leading questions
- use simple grammatical structures
- avoid wording which seems to expect a particular answer
- avoid unreasonable length
- etc.

ii Analysts must know how to conduct interviews:
- avoid leading questions
- avoid talking too much
- gain cooperation of operator
- be able to make written records & notes
- etc.

iii Analysts must be completely competent in operating hardware:
- know sensitivity of audio tape recording equipment
- know sensitivity and dynamic range of video equipment
- practise handling equipment to avoid disruption of recording
- practise use of data logging equipment if used

6.1.2 Training in Vocabulary and Recording Formats

i Analysts must be fully trained in the list of action verbs allowed and their definition.

ii Analysts must be well briefed in the technical vocabulary of the particular industry being investigated to facilitate communication with job incumbents.

iii Analysts must be familiar with the general structure and principles of organization of the data base management system which will be used.

iv Analysts must be practised in using the recording charts, data loggers, etc. so that there is no ambiguity about how information is to be entered.

6.1.3 Reliability and Validity

i At least one "standard task" is required, specially constructed and with carefully prepared "operators" who will carry out the task in standard and non-standard ways. The "operators" are in effect actors not real operators.

ii Each analyst should perform an analysis of the standard task on more than one occasion with an interval of at least several days between them.

iii Reliability can be assessed by comparing the two (or more) analyses of the "standard task" by several different analysts. A completely reliable operator will produce identical analyses on different occasions.

iv Reliability of the TA team can be assessed by comparing the analyses performed on a single "standard task" by several different analysts. A completely reliable team should produce identical descriptions.

v Slight differences are to be expected, but if different verbs or nouns are used sufficient to result in conflicting classification by the data base, either the TA method or the TA analysts are unreliable and improvements are required.

vi Validity can be assessed in two ways:

i The description of the task generated by the analyst should match exactly the script acted by the operator.

ii A novice should be able to perform the task by following the steps described in the task analysis.

vii Paradigming is the process used to generate a missing procedure when a gap is found in the course of task analysis. It is not necessary that all analysts should generate identical paradigms for a particular 'gap' in procedures, nor that "an individual analyst should generate the same paradigm if confronted with a similar 'gap' on different occasions. But all analysts must be able to,

a) describe clearly the situation requiring paradigming;

b) describe the behaviour used in practice by operators reliably and validly;

c) reliably report the existence of paradigming and reliably enter its occurrence in the data base

6.1.4 Preparation for Selected Analysis

i A task analysis method supplies a list of standard action verbs, nouns, and categories. But a particular analysis requires the analyst to add the specific vocabulary to the generic TA vocabulary. Each analyst must have sufficient background preparation in the technical vocabulary of the industry to ensure the correct choice of language and an ability to discuss ambiguities with operators.

ii Each analyst must undergo familiarization with underlying engineering and even architectural principles. This is because it is the responsibility of the analyst to discover cases where operations defined by engineering design have not been translated into procedures.

6.1.5 Comments

This outline describes an ideal situation which will guarantee a task analysis of the highest quality. It is extremely rare that all these steps are carried out in detail for a particular investigation.

If an organization is intending to set up its own task analysis team, all the steps should be undertaken.

If an organization hires a task analysis consulting company to perform task analysis, the consultants should be asked to establish their practice in respect of all the above items.

It is rare to find the "standard task" method of establishing reliability and validity. It is rare to find a check being done on the engineering specifications which lie behind the procedures. Both steps are extremely desirable.

It is expensive to carry out all the above steps. The level of reliability and validity obtained is directly a function of the cost an organization is prepared to accept.

6.2 Preparing for a Task Analysis: Methods and Equipment

6.2.1 Preparations for Paper and Pencil Methods

The reader is urged to read the relevant section of DOE/EP-0095.

The following decisions must be made.

i What questionnaires will be required?

(a) can standard ones be used with modified vocabulary?

(b) must new ones be designed?

ii What kinds of interviews will be carried out?

(a) checklists?

(b) structured open ended?

(c) closed questions?

(d) what forms are required?

iii What task analysis recording forms (data forms) will be required?

(a) can standard ones be used?

(b) must new ones be designed?

iv Must graphical methods, flow charts, special symbols be designed, learned or used?

(a) should those in use in the industry be used?

(b) should the task analyst's set be used and does it need modification?

6.2.2 Choice and Preparation of Hardware

i Prepare printed forms for questionnaires and interviews.

ii Test data loggers for ease of use, error rates and compatability with complete data bases.

iii Test audio recording for noise rejection, intelligibility. Is stereo needed to enhance intelligibility?

iv Test video equipment for sensitivity and dynamic range.
- How many cameras required?
- Position of cameras?
- Portable or fixed?

v Establish lighting levels.
- Is subsidiary lighting required?
- Will lighting be tolerable to operators?

vi Check location for study.

- Is a dedicated room available?
- Can materials be stored conveniently at the site?
- Can a terminal be made available for on-line entry to data base?

vii Are all books and documents available?

- Procedures
- Manuals
- Management guidelines
- Photographs and diagrams of control room
- Architectural drawings as required
- Engineering manuals

viii Is access to a simulator assured?

- Level of fidelity
- Data logging available
- Performance measurement system available

ix Check properties of computer.

- data base software
- data entry
- transfer of data from records to computer

x Are analysts familiar with hardware to the extent of being able to cope with faults during recording? If not, are spares available to minimize downtime and interruptions?

xi Are all data recording systems capable of continuous operation for an entire session without breaks?

6.3 Preparing for a Task Analysis: Liaison with Industry

The following questions must be resolved before the task analysis begins.

6.3.1 Management, Unions and Operators

i The plan for task analysis in all details must have management approval.

ii The plan for task analysis in all details must have agreement from unions as applicable to all or any personnel required in the course of the analysis.

iii The operators must be briefed as to the nature and purpose of the analysis.

NOTE: One question which must be resolved to the satisfaction of all parties is the degree of anonymity of data collected, and what will be done if abnormal, unusual or non-standard behaviour is discovered in the course of the investigation.

6.3.2 Organization of Task Analysis

i How many staff at each level will be available?

Operating staff
Maintenance staff
Training staff
Supervisory staff
Management

ii What space is available?

- for interviews
- table top analysis
- storage of equipment

iii What access to the simulator will be provided?

iv What schedule of access to the control room will be provided?

v What is the availability of the staff listed under 6.3.2 (i) above?

vi Can on-line connection be provided to the data base computer?

vii Are adequate power outlets, cables, etc. available at all locations?

viii Can all equipment, manuals, records, etc. be kept secure?

6.4 Preparing for a Task Analysis: Data Base Management

6.4.1 Check Computer Hardware

i Is the hardware compatible with other systems which may be used at other stages of the investigation?

- during data acquisition
- during data analysis
- during report preparation
- during integration of data from this investigation with data from other investigations
- during subsequent use of data for modification of practice by the utility

ii Is the capacity of the hardware adequate for the amount of data which will be generated?

iii How will long term storage of the data be handled?

6.4.2 Check Computer Software

i Is the data management system able to handle the quantity of data to be generated?

ii Is the classification scheme appropriate?

iii Is there provision for querying the data base in a variety of ways?

iv Has the query system been made compatible with all questions which are foreseen?

v Can the system be easily modified if new categories, structures, and queries are required during and after the investigation?

vi Can the database system be used by analysts and others without the need to learn details of the programming language? Can operations be carried out in the language of the analysis rather than in the programming language?

vii Is the software able to communicate with other systems, at the utility, at the AECB, and other places where the data may be required?

viii Is the software powerful enough to handle problems of statistical analysis, hard copy production, and long term storage?

6.4.3 Long Range Planning

Both hardware and software should be planned so that data from several task analyses can be interrelated. Because task analyses are expensive and resource intensive, every effort should be made to ensure that later analyses can be coordinated with the records of existing data bases. For example, the codes used to label the entries in the data base should have enough symbols to allow for identification of the source of the analysis, the names of the companies and perhaps even personnel who carried out the analysis, etc.

Careful planning at this stage will contribute substantially to cost effectiveness of an extended program of analysis to be carried out at different installations within a single industry.

A well organized data base can contribute to the cost effectiveness, of design, operation, maintenance, training, productivity and safety throughout the industry.

7.0 A PREFERRED METHOD OF JOB AND TASK ANALYSIS APPLICABLE TO NUCLEAR POWER PLANTS

This section consists of two items which together describe our recommended task analysis procedure.

The first is a flowchart which shows how to plan the sequence of operations required to complete a task analysis of a nuclear power plant. It includes job analysis, preparation of vocabulary and taxonomy, preparation of data base, choice of tasks, training of personnel, and the phases of the actual task analysis (Table Top, Walkthrough/ Talkthrough, and Simulator study), validation and quality control, entry of results into the data base, and an indication of routes by which the data base can support a variety of subsequent activities aimed at increasing nuclear safety.

The second item is a set of comments. Each step in the flowchart is numbered, and the comments refer to clusters of numbers, emphasizing problems which are particularly important in carrying out the appropriate step in the flow chart.

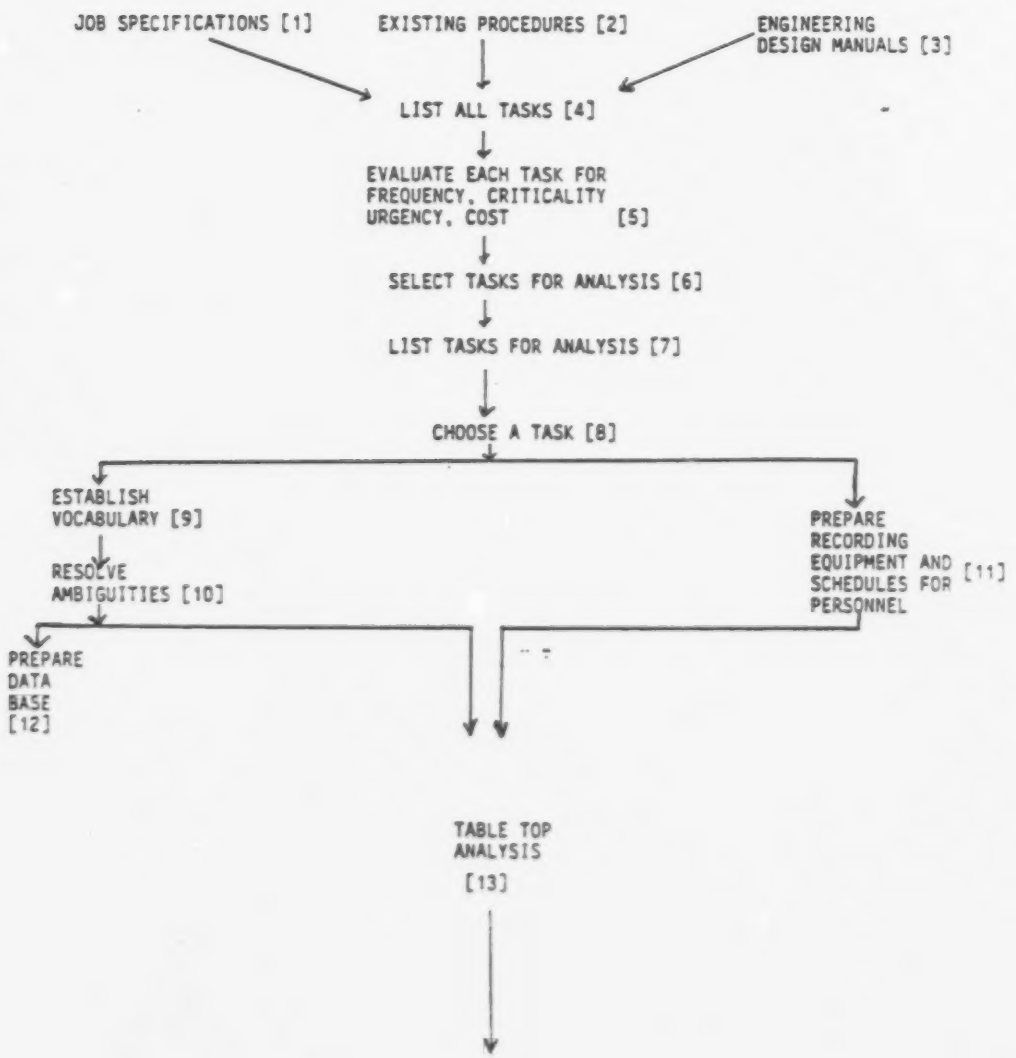
Taken together the chart and comments should ensure that all the required steps for a complete task analysis on identified and completed. If any are omitted, the chart provides a convenient way of noting that fact.

Section 7 complements the descriptions of the Task Data Form and the Data Base.

7.1.F1

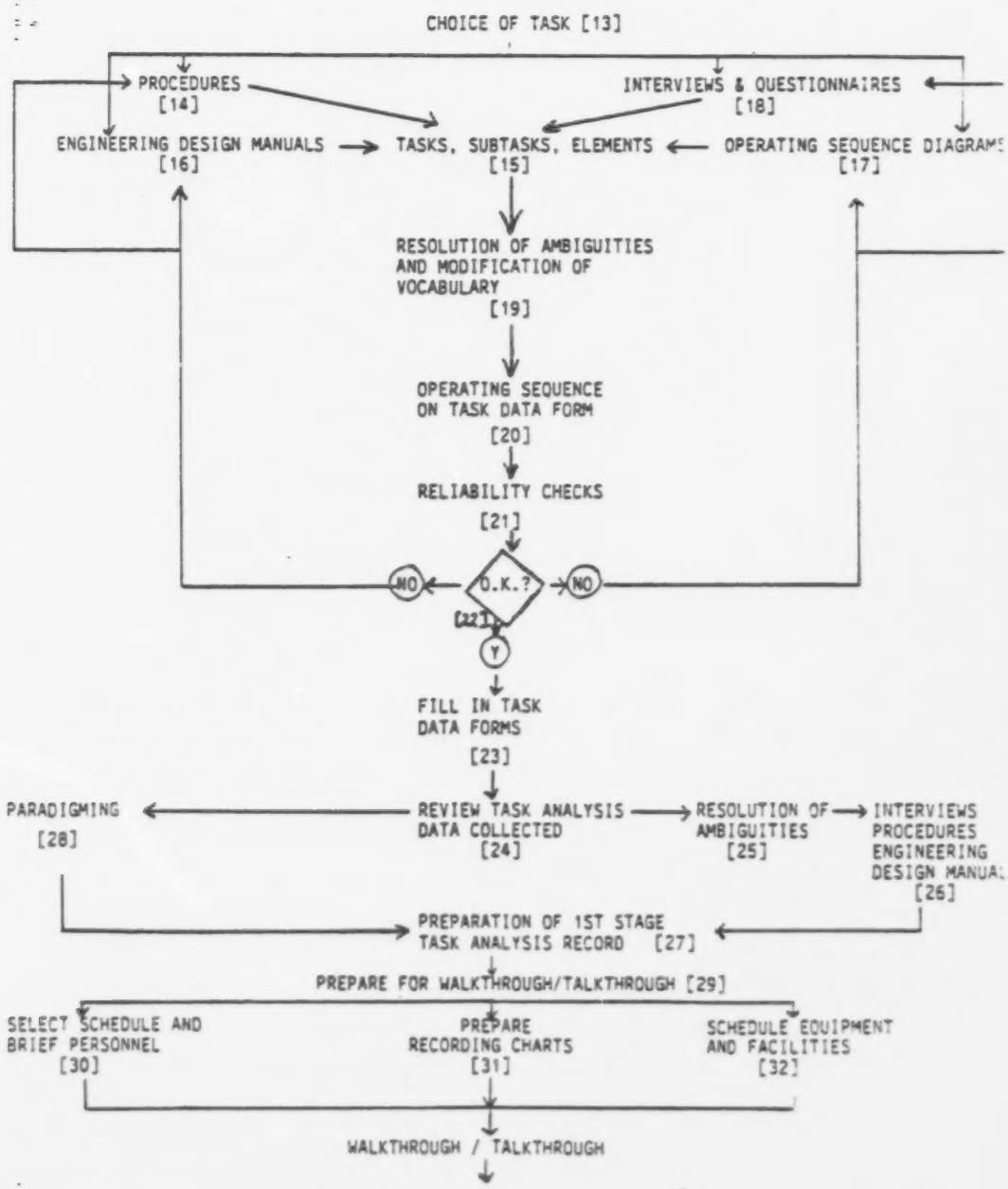
A METHOD OF TASK ANALYSIS FOR NUCLEAR POWER PLANTS

TASK ANALYSIS FLOW CHART

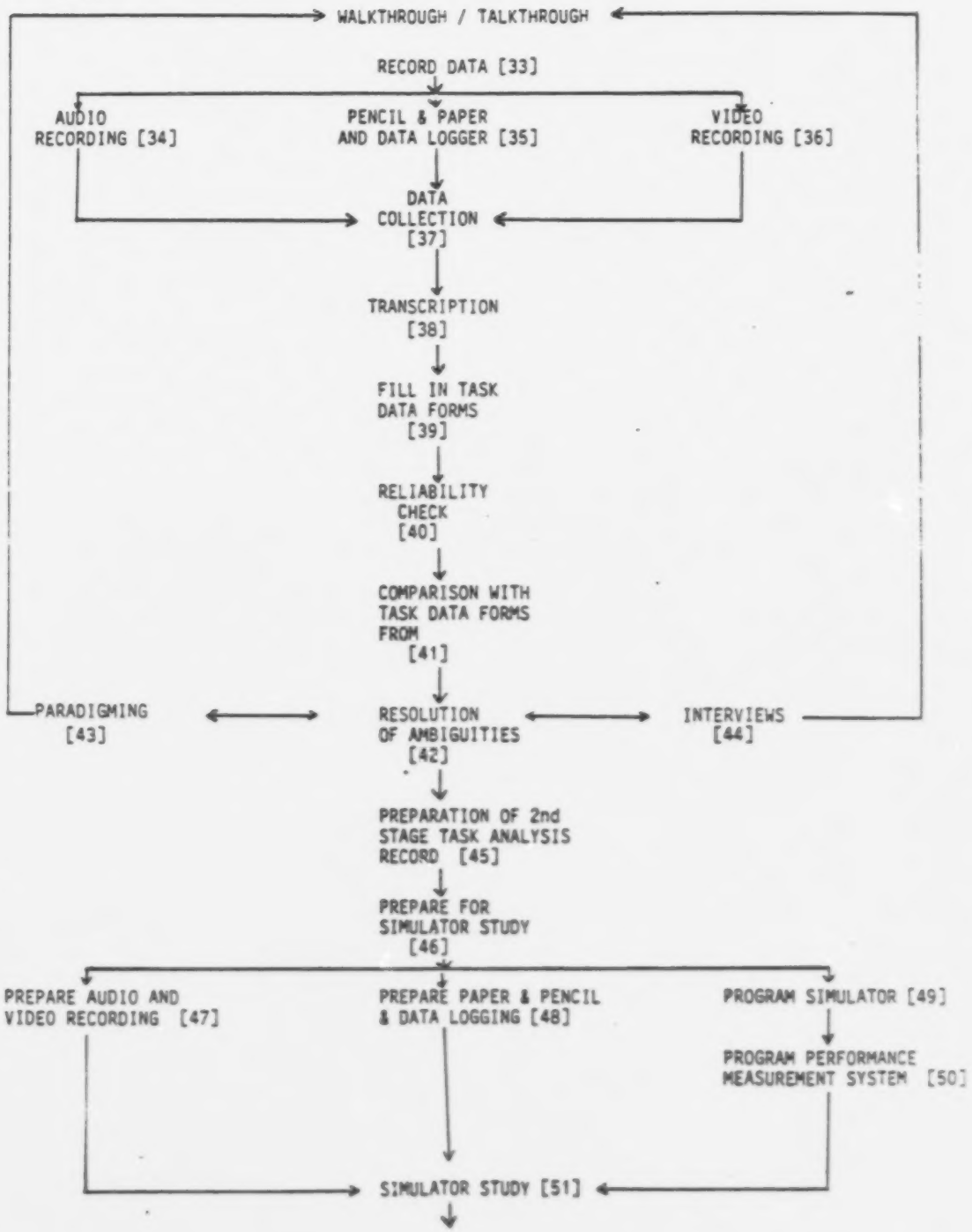

JOB SPECIFICATIONS [1]
EXISTING PROCEDURES [2]
ENGINEERING DESIGN MANUALS [3]
LIST ALL TASKS [4]
EVALUATE EACH TASK FOR FREQUENCY, CRITICALITY URGENCY, COST [5]
SELECT TASKS FOR ANALYSIS [6]
LIST TASKS FOR ANALYSIS [7]
CHOOSE A TASK [8]
ESTABLISH VOCABULARY [9]
RESOLVE AMBIGUITIES [10]
PREPARE RECORDING EQUIPMENT AND SCHEDULES FOR PERSONNEL [11]
PREPARE DATA BASE [12]
TABLE TOP ANALYSIS [13]

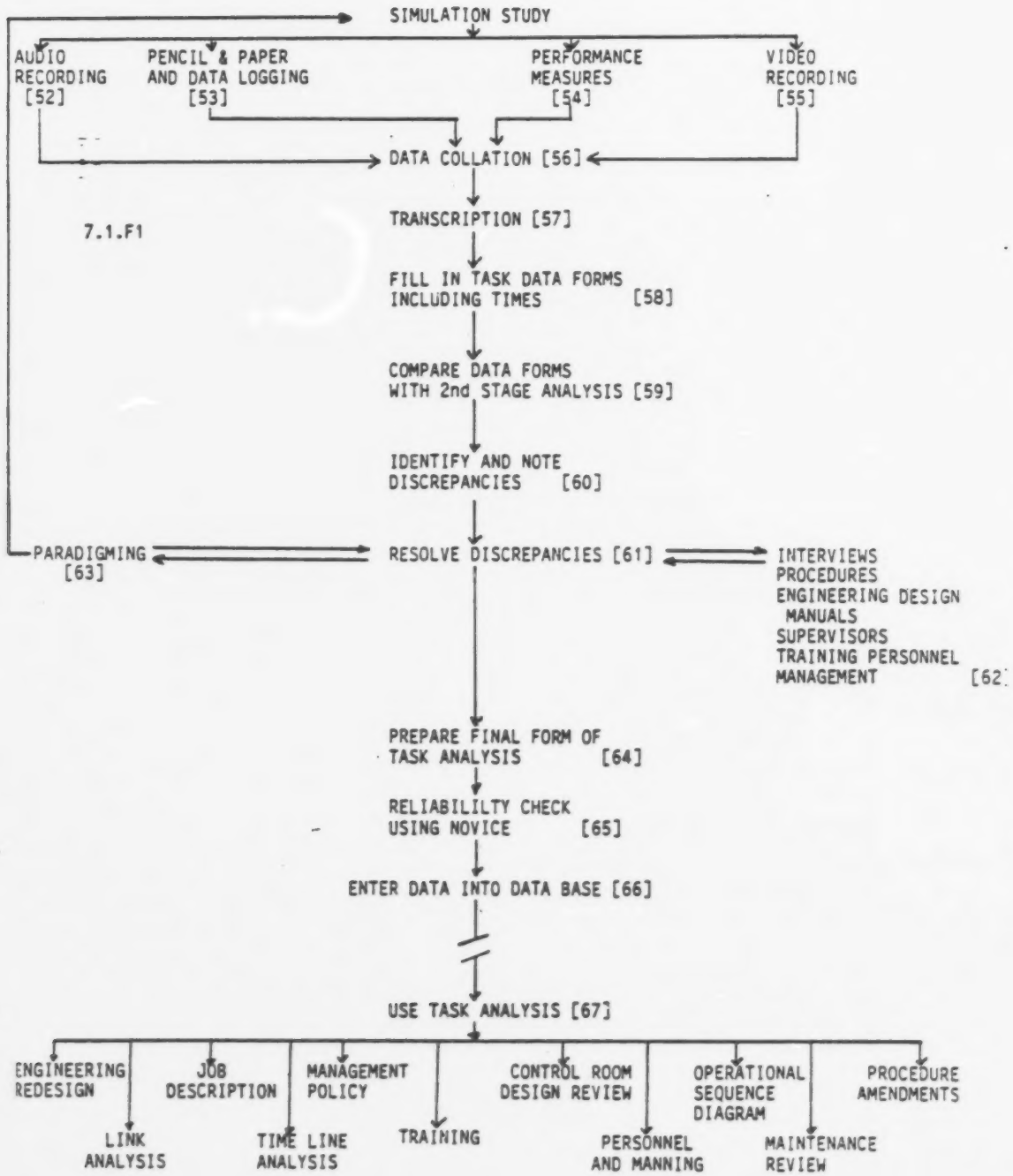
7.1.F1

TABLE TOP ANALYSIS


CHOICE OF TASK [13]
PROCEDURES [14]
INTERVIEWS & QUESTIONNAIRES [18]
ENGINEERING DESIGN MANUALS [16]
TASKS, SUBTASKS, ELEMENTS [15]
OPERATING SEQUENCE DIAGRAMS [17]
RESOLUTION OF AMBIGUITIES AND MODIFICATION OF VOCABULARY [19]
OPERATING SEQUENCE ON TASK DATA FORM [20]
RELIABILITY CHECKS [21]
O.K.?
NO
NO
[22]
Y
FILL IN TASK DATA FORMS [23]
PARADIGMING [28]
REVIEW TASK ANALYSIS DATA COLLECTED [24]
RESOLUTION OF AMBIGUITIES [25]
INTERVIEWS PROCEDURES ENGINEERING DESIGN MANUALS [26]
PREPARATION OF 1ST STAGE TASK ANALYSIS RECORD [27]
PREPARE FOR WALKTHROUGH/TALKTHROUGH [29]
SELECT SCHEDULE AND BRIEF PERSONNEL [30]
PREPARE RECORDING CHARTS [31]
SCHEDULE EQUIPMENT AND FACILITIES [32]
WALKTHROUGH / TALKTHROUGH

7.1.F1


WALKTHROUGH / TALKTHROUGH
RECORD DATA [33]
AUDIO RECORDING [34]
PENCIL & PAPER AND DATA LOGGER [35]
VIDEO RECORDING [36]
DATA COLLECTION [37]
TRANSCRIPTION [38]
FILL IN TASK DATA FORMS [39]
RELIABILITY CHECK [40]
COMPARISON WITH TASK DATA FORMS FROM [41]
PARADIGMING [43]
RESOLUTION OF AMBIGUITIES [42]
INTERVIEWS [44]
PREPARATION OF 2nd STAGE TASK ANALYSIS RECORD [45]
PREPARE FOR SIMULATOR STUDY [46]
PREPARE AUDIO AND VIDEO RECORDING [47]
PREPARE PAPER & PENCIL & DATA LOGGING [48]
PROGRAM SIMULATOR [49]
PROGRAM PERFORMANCE MEASUREMENT SYSTEM [50]
SIMULATOR STUDY [51]


SIMULATION STUDY
AUDIO RECORDING [52]
PENCIL & PAPER AND DATA LOGGING [53]
PERFORMANCE MEASURES [54]
VIDEO RECORDING [55]
DATA COLLATION [56]
TRANSCRIPTION [57]
FILL IN TASK DATA FORMS INCLUDING TIMES [58]
COMPARE DATA FORMS WITH 2nd STAGE ANALYSIS [59]
IDENTIFY AND NOTE DISCREPANCIES [60]
PARADIGMING [63]
RESOLVE DISCREPANCIES [61]
INTERVIEWS
PROCEDURES
ENGINEERING DESIGN
MANUALS
SUPERVISORS
TRAINING PERSONNEL
MANAGEMENT [62]
PREPARE FINAL FORM OF TASK ANALYSIS [64]
RELIABILILTY CHECK USING NOVICE [65]
ENTER DATA INTO DATA BASE [66]
USE TASK ANALYSIS [67]
ENGINEERING REDESIGN
JOB DESCRIPTION
MANAGEMENT POLICY
CONTROL ROOM DESIGN REVIEW
OPERATIONAL SEQUENCE DIAGRAM
PROCEDURE AMENDMENTS
LINK ANALYSIS
TIME LINE ANALYSIS
TRAINING
PERSONNEL AND MANNING
MAINTENANCE REVIEW

7.1.F1

7.2 Commentary on Proposed Method of Task Analysis

The numbers refer to the numbers in the Task Analysis Flowchart in Figure 7.1.F1

[1] From job descriptions, procedures manuals and [2] engineering design manuals a complete list of all [3] tasks is drawn up. It is important that reference be [4] made to the engineering manuals. It is always possible that during the construction and development of a NPP procedure writers have overlooked the existence of some piece of equipment, or have made a mistake concerning its use or properties. This will not be discovered by examining job descriptions or procedures, but only by referring back to initial engineering design. The same problem can arise if equipment is upgraded, changed, or retrofitted: the implications for operating procedures may not be realized, or may be incorrectly interpreted; or changes to procedures may not be promulgated due to oversight.

[5] Because of the high cost and inconvenience of task [6] analysis, it is probable that only some tasks will be analyzed. Obvious criteria for choosing candidate tasks include the severity of consequences following incorrect task performance, frequency of task, relation to other tasks, the amount of time available and the load on the operator in carrying out the task, etc. It is the responsibility of the authority commissioning the task analysis to decide which tasks should be analyzed. Note the special need for considering tasks involved in dealing with unforeseen emergencies ("non-design" emergencies) for which explicit procedures do not exist.

[9] Task analysis requires the use of a standardized [10] vocabulary to ensure validity and reliability. It is probable that the action verb list will be a standard one. But it may be necessary to add new verbs for particular situations. It is always necessary to agree on the definitions of the nouns to be used, the titles of operators, the names and descriptions of control room hardware, etc. These are always industry specific, and may be job specific or task specific. The task analysis team must [11] prepare a complete vocabulary and resolve any ambiguities.

[12] The resulting vocabulary together with the syntax of the task data chart will determine the entries in and structure of the data base. Other items such as the names of the task analyst, name of the analysts' company, name of the utility, sources of information, etc. will have to be encoded. It is important that as the structure of the analysis develops there should be interaction between the data base management team and the task analysts to assure a correct and powerful data base development.

[13] Table top analysis. This stage includes everything [14] that can be done without actually having to enter the [15] control room or simulator. Its result is the most [16] detailed description of the task which can be made "off [17] site". In general the sequence should be as shown on [18] the flow chart. The task analysis team should do as [19] complete a job as possible of analyzing the task down [20] to its elements using the manuals and other documents available. Only when stages [14] - [17] have been completed should interviews and questionnaires be used to check on the accuracy of the analysis, since

interviews and questionnaires are time consuming to prepare, use and analyze, and the utility personnel required for their use are an expensive and busy resource. The interviews and questionnaires are directed at subject matter experts (SME) and are used to resolve any ambiguities in the task and element list, to check on the vocabulary, and to establish that nothing has been omitted which should be in the task description, and nothing included which is not intended practice. Note that SME may include any or all of the following: operators, supervisors, trainers, procedure writers, engineering staff, designers, maintenance personnel, component equipment vendors, and management, depending on the particular problems which arise. There have been well documented cases in various industries where the intention of the design engineer, the equipment supplied by a vendor, the written procedures, the rules laid down by management, the practice of operators and the effect of maintenance have been more or less at variance. The intention of the task analysis at step [20] is to have a canonical prescriptive account of how the utility intends that the task must be performed.

[21] It is important to perform some kind of quality control [22] and reliability check. If several task analysts are involved each should independently prepare a task data form (TDF) for a single task, and the results should be compared to ensure that they are identical. A single analyst should prepare two TDFs for a single task, the second independently of the first. If the organization performing the analysis has the appropriate manpower, one of its own experts should examine the TDFs for consistency and reliability and to resolve discrepancies. A check should be made for consistency with the requirements of the data base, and the latter (the data base) coding etc. be altered as required.

[23] This step completes the first stage task analysis.

[24] There will be gaps and ambiguities in the data at this [25] stage. In some cases these will be resolvable by [26] renewed recourse to SMEs as before. In addition, it [27] may be that subtasks or elements are discovered [28] which occur, which are not official, but which are necessary for operating the plant. (Operators may describe elements which they have invented to cover a deficiency in the procedures.) If possible an agreed description ("canonical description") of the task, sub-task or element should be drawn up from discussions, interviews and questions to SMEs who perform the task. This description should be marked as such for entry in the data base. The process is called "paradigming".

[29] Although it is possible to "talk-through" a task in a [30] table-top setting, it is recommended that a combined [31] "walk-through/talk-through" (WTTT) be performed in a [32] simulator or in the control room. If a simulator is used it need not be a dynamic simulator but it must be an exact static copy of the control room to scale. Since the operator will not actually perform any actions the real control room can be used if time, space and operations allow. But care should be taken to ensure that the operator does not inadvertently actually carry out an action by mistake. Note that if tasks involve more than one member of a team the analyst will have to decide whether to do the WTTT with all members involved or whether to ask the operator to describe what he would do for the range of actions which might be taken by the other members of the team.

[33] Note that the paper and pencil notes made by the [34] analyst while the operator does the WTTT, may be of [35] very great importance. There may be practical problems [36] of getting detailed video recording and audio [37] recording. The notes may be able to resolve [38] ambiguities in the audio and video record.

[39] If possible the transcribed and collated data should be used to prepare a second set of TDFs independently of the Table Top TDFs. If this is not possible, data from the WTTT should be clearly distinguished from that derived from the Table Top phase using different colours.

[40] Note that at this stage the data are a mixture of [41] prescriptive and descriptive. If the procedures are [42] complete and exhaustive, necessary and sufficient, and [43] if the operators are perfectly trained and management [44] policies unambiguous and in accord with procedures, then in the WTTT all and only that behaviour defined by the procedures will be seen. If that is so, then the only check needed is with engineering design to make sure that there are no inadvertent inaccuracies in the procedures. If there are discrepancies they must be resolved by interviews, questionnaires, paradigming, or a repetition of the WTTT.

[45] The Task Data Form at this stage should be virtually [46] complete with regard to the prescriptive task analysis. The final stage, the simulator study, is to see whether the behaviour remains the same when the operator carries out the task in real time rather than slowly and with a running commentary.

[50] All training simulators should include Performance Measurement Systems (PMS). That is, they should be able to record the state of all components (switches, knobs, dials, etc.) and the values of all state variables at all moments. The sampling rate should be appropriate to the system bandwidth. In addition all communications should be recorded. From these data it should be possible to reconstitute an exact record of the progress of the task, and the timing, sequencing, and effect of each element and action. In addition a video recording should be made of the movements of the operator about the control room. If the simulator does not have a PMS then intensive data logging by audio and visual recording and by paper and pencil will have to be relied on. Note that a PMS cannot record "cognitive" behavior.

[58] This record is the basis of descriptive task analysis DTA. In particular it now contains two new and important types of data for control room design review: (1) the movements of the operator about the control room. (2) the time taken to carry out tasks, subtasks and elements under realistic conditions. Note that empirical evidence suggests that the time taken to decide what task to carry out may be shorter by an order of magnitude in a simulator than in the field situation (Beare et al, 1983). It is not known whether the time taken to complete the task once initiated is different. Again the source of the data (Table-Top, WTTT, or simulator) must be kept clear.

[61] Note that resolution of ambiguities by iteration [42] through WTTT and Simulation are costly and time consuming. Such iterations should however not be shirked if necessary to resolve ambiguities.

[63] This TDF is the one from which the people responsible for entering data into the data base will work. The usefulness of the task analysis depends on the completeness and accuracy of this TDF. Note that taxonomic coding must be unambiguous. For example, is the time for a task or element the prescribed time (as required by procedures ("Switch 29 must be closed within 15 seconds") or described time ("switch 29 was closed after 17 seconds").

[65] At this point a final reliability check is possible for the sequence, but not for the times prescribed. If the task analysis is correct, and if the data on which it is based are accurate, an untrained operator should be able to carry out the task by stepping through the description of actions as written on the TDF. If he cannot, then either the task analysis is defective, or the simulator is not high fidelity, or the procedures are inadequate, or the control room is badly designed.

[66] Steps must be taken to check the accuracy of data entry. The known error rates of keypunching by human operators are high enough to introduce significant errors in data of this magnitude. Particularly in non-redundant random strings, such as taxonomic category codes, undetected error rates may reach more than 1 in 1,000 keystrokes - one or two in the number of symbols on a page of this report.

[67] See Section 1.3 on Uses of Task Analysis

8.0 PROCEDURE FOR ASSESSING PROPOSED TASK ANALYSIS METHODS

8.1 Principles of Assessment

In view of the regulatory style of the AECB it is to be expected that utilities will propose their own methods of task analysis, which may be more or less complex than the method discussed in this document. This section provides guidelines for assessing such proposals.

There are several questions which must be answered when any task analysis method is being assessed.

1. Has the method been developed by people experienced in human factors in general and task analysis in particular?

2. Will the TA be carried out by a properly trained TA team?

3. Will all the appropriate steps be taken to make the analysis at least as complete as the AECB reference TA?

4. Is quality assurance included in the TA?

5. Will the results be compatible with the general CANDU data base which is being built up?

6. Will the computer data base generated be able to communicate with the general CANDU data base?

As with task analysis itself, the important thing is to ensure that the assessment is carried out systematically and in detail. Several methods are possible. For a preliminary assessment, the following checklist may be used.

8.2.T1 TASK ANALYSIS EVALUATION FORM

Licensee _____ AECB IDENT. _____

Reactor Type _____

1. Type of Task Analysis PRESCRIPTIVE [] COMBINED []
DESCRIPTIVE []

2. Level of Detail TASK [] SUBTASK [] TASK ELEMENT []

3. Preliminary Task Analysis PAPER & PENCIL [] OTHER []

Materials Used
- WRITTEN PROCEDURES []
- SYSTEM PLANS []
- TRAINING MATERIALS []
- DESIGN MANUALS []
- OTHER _____

	YES	NO
Is Task Data Form Compatible with AECB Task Data Form?	[]	[]
Is Task Data Form Complete?	[]	[]
Is Task Data Form compatible with data base?	[]	[]

4. Methods of Task Analysis Components

- TABLE-TOP []
- WALK-TALKTHROUGH []
- SIMULATOR []
- CONTROL ROOM []
- OTHER [] _____

A. Table-Top Component

Who of the following are to be involved in the table-top component if used?

- OPERATORS (WORKING) []
- OPERATORS (PAST) []
- TRAINERS []
- SUPERVISORS []
- OTHER
  e.g. Systems designs []

B. Walk-Talkthrough Component

Which of the following aids will be used?

MANUALS	[]
FULL SIMULATOR	[]
PARTIAL SIMULATOR	[]
MOCK UP	[]
CONTROL ROOM	[]
OTHER	[]

C. Simulator Component

What features does the simulator have?

PLANT STATUS LOGGING	[]
PMS	[]
BIOLOGICAL INFO.	[]
OTHER	[] _____

What techniques will be used for data collection?

VIDEO OBSERVATION	[]
FILM OBSERVATION	[]
AUDIO RECORDING	[]
PMS	[]
BIOLOGICAL INFO. (e.g. eye movements, etc.)	[]
ANALYST'S WRITTEN RECORD	[]

5. Vocabulary

Are all verbs to be used listed and defined?

YES [] NO []

Is the Berliner Taxonomy used? YES [] NO []

In not, what taxonomy will be used? _____

_____

Is a copy of the taxonomy attached? YES [] NO []

Are all nouns defined and listed? YES [] NO []

SUBJECTS	[]
OBJECTS	[]

8.2 .T1 TASK ANALYSIS EVALUATION FORM

6. Data

Will the standard AECB Task Data Form be used? YES [] NO []

If not, Which of the following data will be included in the task analysis for the prescriptive and descriptive components?

DATA	PRESCRIPTIVE (expected)	DESCRIPTIVE (observed)
1. Plant Identification		
2. Error Rates		
3. Problems		
4. Task difficulty		
5. Task criticality		
6. Duration (Start/finish times)		
7. Function		
8. Task		
9. Subtask		
10. Location of task		
11. Component used (displays/controls)		
12. Cue		
13. Feedback		
14. Skills required		
15. Knowledge required		
16. Who will carry out task		
17. Frequency of task		
18. Procedures involved		
19. Action - physical and cognitive		
20. Other tasks parallel to task		
21. Frequency of task		

Why will the AECB Task Data Form not be used? _____

_____

Which columns of the AECB Task Data Form are missing? _____

_____

7. Personnel Responsible for T.A.

Number of Analysts PRINCIPAL _____
TECHNICAL _____
JUNIOR _____

Level of Training and Experience		TYPE	TRAINING	EXPERIENCE
	1.			
	2.			
	3.			
	4.			
	5.			
	6.			
	7.			
	8.			
	9.			

8.2 .T1 TASK ANALYSIS EVALUATION FORM

8. Time Allotted to Task Analysis

TOTAL TIME _____ person weeks

TIME FRAME _____ months

TIME FOR EACH ANALYST
1. _____ person weeks
2. _____
3. _____
4. _____

EACH TECHNICIAN
1. _____
2. _____
3. _____
4. _____

JUNIOR PERSONNEL
1. _____
2. _____
3. _____
4. _____

9. Computerization of the Data

			EASE OF DATA ENTRY		
			EASY	DIFFICULT	VERY DIFFICULT
Form of Data	QUESTIONNAIRES	[]	1	2	3
	DATA SHEETS	[]	1	2	3
	PHYSIOLOGICAL	[]	1	2	3
	DATA RECORDERS	[]	1	2	3
	NOTES	[]	1	2	3

Possible Analyses
- HUMAN RELIABILITY []
- LINK ANALYSIS []
- TIME LINE []
- TASK DIFFICULTY []
- TASK CRITICALITY []
- OTHER []
  1. _____
  2. _____
  3. _____
  4. _____

B.2.T1 TASK ANALYSIS EVALUATION FORM

10. Will the task analysis verify the following:

PROCEDURES	[]
EQUIPMENT LAYOUT	[]
EQUIPMENT DESIGN	[]

11. Will the task analysis be able to handle more than one procedure for a single task? EXPLAIN _____

_____

_____

_____

12. Will the task analysis provide procedures that can be consistently identified with complex parallel procedures as well as simple, singular procedures? EXPLAIN _____

_____

_____

_____

13. In view of the responses to items 11 and 12 above, will the task analysis be able to handle the changing, complex tasks involved in supervisory control using CRT's in a nuclear power plant control room? EXPLAIN _____

_____

_____

_____

14. What Quality Assurance checks will be used? _____

_____

15. What Data Base will be used? _____
On What Computer? _____

16. Is the Data Base Fully Compatible with the existing CANDU data base?

8.3 Use of Evaluation Form

The answers to the checklist should be assessed in comparison with the recommendation of this document, and particularly against the flow chart in Section 7 and the notes thereto. Can the licensee's proposed method ensure that all steps in Section 7.0 will be successfully carried out?

It is not practical to provide a completely exhaustive and detailed checklist which can be guaranteed to assess the quality of a proposed TA method when administered by personnel unfamiliar with task analysis and human factors. There is always a considerable amount of art and informed judgement required in such assessments, and it is assumed that the AECB will either have suitable human factors specialists on its staff, or will employ them on a consultancy basis. But any proposed method which has difficulty in providing detailed answers to the checklist, or which provides answers substantially different from those which would be generated by the method recommended in this document should only be accepted after detailed examination and clarification to the satisfaction of the AECB's personnel or their qualified consultants.

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DOE/EP-0095. Guidelines for Job and Task Analysis for DOE nuclear facilities. U. S. Department of Energy, Office of Nuclear Energy, Washington, D.C., 1983.

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NUREG/CR-3371. Task Analysis of Nuclear Power Plant Control Room Crews. Burgy, D., Lempages, C., Miller, A.., Schroeder, L., Van Cott, H., Paramore, B. 1983.

NUREG/CR-3415. Nuclear Power Plant Control Room Task Analysis: Pilot Study for Boiling Water Reactors. Barks, D., Gower, F., Kozinsky, E. & Moody, G. 198_.

NUREG/CR-3606. Nuclear Power Plant Control Room Crew Analysis Database: SEEK System. Burgy, D. & Schroeder, L. 1984.

10.0 TASK ANALYSIS ANNOTATED BIBLIOGRAPHY

The following annotated bibliography provides a summary of the documents most relevant to task analysis methodology as applicable to NPP control room design and review.

Each entry is broken down into a number of subheadings. Under the entry "General" are given the source and the objective of the document, and our recommendations. The source allows the reader to decide quickly whether the document is likely to be of direct (nuclear) or indirect (e.g. military) relevance. The objective of the document is the objective indicated by the document's original author or authors. "Discussion and Recommendations" summarizes our opinion about the quality and usefulness of the document for NPP applications.

Under the entry "Characteristics of the Method" will be found summary statements concerning such factors as the type of task analysis (prescriptive or descriptive), the methods to be used, the degree to which the data can be expected to give a complete task analysis if the method is followed, and the time, resources and personnel required.

Note that a complete copy of DOE/EP-0095 is provided in microfiche form attached to the back cover of this report.

ANALYSIS AND TECHNOLOGY, INC. Guidelines for Job and Task Analysis for DOE Nuclear Facilities. DOE/EP-0095. 1983. U.S. Department of Energy, Office of Nuclear Energy, Washington, D.C. 20545.

A. General

1. Source

Nuclear

2. Objectives of this Document

To give a complete description of how to prepare and carry out a prescriptive and descriptive task analysis, and set up the relevant data base. It discusses in detail the uses to which task analysis can be put.

3. Discussion and Recommendation

THIS IS THE SINGLE PREFERRED REFERENCE. It is exceptionally thorough, and describes how to prepare and train task analysis personnel as well as how to carry out the analysis. In addition there is an extensive discussion of how to design the computer data base to store and access the results of the task analysis. The only obvious limitation is that methodological problems specifically related to "advanced" control rooms are not covered. Discusses what to do if a gap in procedures is found during task analysis. IF AN EXISTING TASK ANALYSIS METHODOLOGY WERE TO BE ADOPTED, THIS SHOULD BE THE ONE.

B. Characteristics of the Method

1. Type of Task Analysis

Prescriptive

2. Data Collection Methods

Table Top
Questionnaire
Interviews
Procedures
Design Manuals
Walk-Through/Talk-Through
Simulator
Subject matter experts
Management
Supervisors

3. Completeness of Data

Complete

4. Extent of Work

Requires (and defines) trained task analysts, for several man months. Some estimates are given.

5. Resources

Total system plus data base computer, simulator, and all personnel.

6. Cooperation

Operators
Engineers
Designers
Trainers
Management
Supervisors
Subject matter experts
Data base manager
Software designers

Bailey, R.W. Human Performance Engineering: A Guide for System Designers. Englewood Cliffs; Prentice Hall, 1982.

A. General

1. Source

Textbook

2. Objectives of the Chapter.

This chapter (11) describes the four major processes of human factors in basic design. These are:

- function analysis and allocation;
- human performance requirements;
- task analysis;
- work modules.

Bailey's focus is on the development of a system plan that provides a design that matches the work to be done with the people whom are to do it. His task analysis is, consequently, a tool to determine staffing requirements and the distribution of work amongst personnel.

3. Discussion and Recommendations.

Bailey's method is sensitive to such variables as task difficulty, task complexity, the skills and knowledge required to carry out tasks. On the other hand the method does not provide adequate data on errors, feedback, timing, location and instruments involved. Furthermore, the method does little to validate the results of its prescriptive analysis. Once "work modules" have been

developed no method is given to validate them (such as a descriptive walkthrough etc.)

B. Characteristics of the Method

1. Type of Task Analysis

Prescriptive

2. Data Collection Methods

Procedures and system plans

3. Completeness of the Data

Prescriptive data is mostly complete; Descriptive data is incomplete.

4. Extent of the Work

Requires a principal analyst with extensive training and experience. Time frame is hard to estimate -- maybe a month or two.

5. Resources

Very little is needed to carry out the analysis other that written procedures, plans etc.

6. Cooperation

Requires aid from systems personnel design engineers.

Barks, D., Gower, F., Kozinsky, E. and Moody, G. Nuclear Power Plant Control Room Task Analysis: Pilot Study for Boiling Water Reactors. NUREG/CR-3415. General Physics Corporation.

A. General

1. Source

Nuclear

2. Objectives of the document.

This project tested a proposed method of task analysis and recommended its use for nuclear power plant control rooms. The research set out to determine the best way to find out what operators should be doing. This objective was approached in view of what the task analysis data could offer the following issues:

- human engineering

- number of operators and their skill and knowledge
- training
- procedures
- job performance aids
- communications policy

3. Discussion and Recommendations.

The research had some secondary objectives that influenced its approach. Firstly the research team wanted to test, in addition to the methodology, the use of simulators to augment the other data collection techniques. Secondly the team were interested in the development of predictive models of operator/system performance.

For the most part, the task analysis method allowed the team to collect data pertinent to all of the areas mentioned above. However, these data were based mostly on the way in which the operators performed rather than as they might perform in the ideal situation. Hence, little prescriptive data were collected.

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive with some prescriptive.

2. Data Collection Methods

- written procedures
- interviews with instructors
- video tapes of C.R. operators (instructors) responding to events in a simulator
- talk-throughs
- Performance measurement system

3. Completeness of data

complete descriptive data
incomplete prescriptive data

4. Extent of Work

Requires a large team of experts and well trained personnel. Job could take months.

5. Resources

- simulator
- video equipment
- computer

6. Cooperation

Require the aid of most personnel involved with the control room.

e.g. - operators and supervisors
- training staff
- technical support staff

Barks, D., Kozinsky, E. and Eckel, S. Nuclear Power Plant Control Room Task Analysis: Pilot Study for Pressurized Water Reactors NUREG/CR-2598. General Physics.

A. General

1. Source

Nuclear

2. Objectives of the Document

This project was carried out to demonstrate the use of task analysis techniques in the nuclear power plant control room setting. A method for task analysis was proposed. The research also evaluated the use of simulator data from a performance measurement system to validate and augment of other task analysis data.

3. Discussion and Recommendations

This research was the first attempt by General Physics at developing a task analysis method for nuclear power plant control rooms. The research team's bias toward a descriptive approach to task analysis began with this project. The team concluded from the study that the use of simulators and video tape records were valuable additions to traditional methods of task analysis. They recommended that the use of these techniques be considered and that video records in particular provide a rich source of data.

Furthermore, this study also marks the initial adoption of the Berliner codes for behaviour for task analysis in NPP control rooms by General Physics. This behavioural code system has been an integral part of this and subsequent task analyses carried out by General Physics and by the Institute of Nuclear Power Operation.

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive with a small prescriptive component

2. Data Collection Methods

- written procedures
- interviews with subject matter experts (control room operators)

- video tapes of the control room operation using a simulator during emergencies
- walkthrough/talkthrough
- PMS data from simulator

3. Completeness of Data

Descriptive data complete
Prescriptive data incomplete

4. Extent of Work

Requires a large team of experts and well-trained personnel. Job may take several months to complete.

5. Resources

- simulator
- video equipment
- computer

6. Cooperation

Requires the aid of some personnel involved with the control room.

e.g. operators and supervisors

Beare, A., Dorris, R., Kozinsky, E., Manning, J., and Haas, P. Criteria for Safety-Related Nuclear Power Plant Operator Actions: Initial Simulator to Field Data Calibration. NUREG/CR-3092, 1983. General Physics Corporation.

A. General

1. Source

Nuclear

2. Objectives of the Document

This report describes the method and results of a study that compared operator response times to emergencies in a simulator environment and in the field situation. The study was carried out in order to produce a set of standards for response times in specific operator activities. The collection of data on these activities represents a basic form of task analysis.

3. Discussion and Recommendations

The data that were collected during this study were of a specific nature (duration of action and error information), though equipment used and location were often indicated. Most of the field data were in the form of Licensee Event Reports.

Simulator data came from the computerized Performance Measurement System (PMS) which was more comprehensive and more accurate. The method is entirely based on past events or what the operator did. No data were/collected regarding what the operator should do.

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive

2. Data Collection Methods

- simulator - PMS
- LER's

3. Completeness of Data

Incomplete descriptive

4. Extent of the Work

Team of analysts with training and experience. With a number of people working together the study may be completed in a couple of months.

5. Resources

- Simulator
- Computer

6. Cooperation

Relatively little needed.

Bell, B. and Swain, A.D. A Procedure for Conducting a Human Reliability Analysis for Nuclear Power Plants NUREG/CR-2254, 1981. Sandia.

A. General

1. Source

Nuclear

2. Objectives of the Document

The report describes "a procedure to be followed in conducting a human reliability analysis as part of a probabilistic risk assessment." Within this procedure is outlined a methodology for task analysis. The objective of the task analysis is to provide descriptive data about tasks in order to determine the

optimal use of human resources with reliability and safety in mind. The method is, therefore, used to provide a model of operator behaviour that can be used to provide a safe, error-free interface with other system components.

This model of operator behaviour is arranged in an HRA event tree showing human error probabilities for each action. Hence, the sequence, timing, error information, criticality and type of task are of utmost importance. This arrangement will allow the analyst to identify those actions where a relatively high probability of error occur, which ones they are and some idea of what can be done to reduce error.

3. Discussion and Recommendations

This task analysis method is to be carried out to determine the "best" way of performing the task. Hence, the method proposed is prescriptive.

B. Characteristics of the Method

1. Type of Task Analysis

Prescriptive

2. Data Collection Methods

- System plans
- procedures
- personal observation and site examination

3. Completeness of Data

incomplete descriptive
more complete prescriptive

4. Extent of the Work

Requires a principal analyst with extensive training and experience. Relatively short (a couple of months).

5. Resources

None in particular

6. Cooperation

- very little from personnel

Burgy, D., Lempages, C., Miller, A., Schroeder, L., Van Cott, H., and Paramore, B. Task Analysis of Nuclear Power Plant Control Rooms: Approach and Methodology. NUREG/CR-3371, 1983. General Physics and Biotechnology.

A. General

1. Source

Nuclear

2. Objectives of the Document

This report describes the procedures and method for task analyses carried out on 8 nuclear plants. The research team focused on describing what operators were doing during emergency operations. The research team found that it was difficult to do a preliminary paper and pencil task analysis. According to the researchers, the written procedures and systems plans did not have enough detail to do a proper job of describing tasks at the level of detail necessary for the goals of the analysis. Therefore, they concentrated on the better data collected during the analysis. These data included video tape records of operators working on a simulator during mock emergency sequences. Hence the analysis became less prescriptive and more descriptive, focussing on what operators did rather than what they should do. Several hundred pages of computer printouts are provided.

3. Discussion and Recommendations

The research was very thorough and entailed the use of the best methods presently available. The main criticism is the lack of a complete prescriptive stage. The table top analysis went some ways towards that aim but would be less capable of providing the "best" rather that currently used procedures that operators should follow. Without a thorough preliminary paper and pencil task analysis that examines both design and procedures information, the "best" way of doing the job will be elusive.

B. Characteristics of the Method

1. Type of Task Analysis

Mostly a descriptive method with some prescriptive input.

2. Data Collection Methods

- Written procedures -- not used to the fullest
- Table-top analysis -- discussion with experts
- Interviews with operators and subject material experts
- Personal observation and video
- Walkthrough/Talkthroughs
- Performance Measurement System or simulator

3. Completeness of Data

Very detailed -- complete and thorough. Volumes 3 & 4 provide over 800 pages of printout of descriptive task analyses similar to that shown in Table 3.2.5.T2 of this report.

4. Extent of Work

Involves a very large team of experts and well trained personnel. Even with a large staff this task analysis could take months.

5. Resources

- video equipment
- simulators
- computer

6. Cooperation

Requires the aid of most personnel involved with the control room.

e.g. - operators and supervisors
- training staff
- technical support staff

Burgy, D. & Schroeder, L. Nuclear Power Plant Control Room Crew Task Analysis Database: SEEK System. NUREG/CR-3606. 1984. General Physics Corporation, 10650 Hickory Ridge Rd., Columbia, Md., 21044.

A. General

1. Source

Nuclear

2. Objectives of this Document

To describe the organization and use of the General Physics data base for descriptive task analysis.

3. Discussion and Recommendation

This document describes the mature data base derived from the methods described in NUREG/CR-3371, "Task Analysis of Nuclear Power Plant Control Room Crews", by Burgy et al, 1983.

B. Characteristics of the Method

Not applicable to this document.

Chu, Y-Y, Steeb, R., and Freedy, A. "Analysis and Modeling of Information Handling Tasks in Supervisory Control of Advanced Aircraft." Air Force Office of Scientific Research, ATR-PATR-1080-80-6, 1980. Perceptronics,Inc., Woodland

Hills, Ca.

A. General

1. Source

Aerospace

2. Objectives of the Document

The report describes a set of methods used to analyze and model pilot behaviour. The methods include a means of describing tasks performed by a pilot during supervisory control of an aircraft.

The task analysis used here is a descriptive type. The intent of the researchers was to identify tasks and task dimensions to quantify and model actions during supervisory control.

3. Discussion and Recommendations

Since the authors had specific goals in mind, this task analysis lacks a prescriptive component and generality. It also does not break tasks down into fine enough detail to be used for applications for all control room tasks.

It does, however, have specific application to the use of computer control of nuclear power plant systems. Many of the CANDU control systems, for example, require that the operator supervise the control system using CRTs and computer-interfaced controls.

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive

2. Data Collection Methods

- Personal observation
- Performance Measurement System
- Procedures

3. Completeness of the Data

Incomplete descriptive

4. Extent of the Work

Requires a principal analyst with strong training and long term experience. No time frame can be estimated.

5. Resources

- Simulator
- Computer

6. Cooperation

Requires help from pilots, trainers and engineers.

Companion, M.H. & Teichner, W.H. Applications of task theory to task analysis. AFOSR-TR-77-1008. 1977.

A. GENERAL

1. Source

U.S. Air Force

2. Objectives of this document
Presents a theoretical quasi-quantitative way to describe a task systematically, using Teichner's behavioural model. The model generates a taxonomy. The model is

$$P = f_1(a) + f_2(S\text{-}S) + f_3(S\text{-}R) + f_4(R\text{-}Ex)$$

P is any measure of performance.

$f_1(a)$ is stimulus acquisition.

$f_2(S\text{-}S)$ is one or more transformations on data.

$f_3(S\text{-}R)$ is translation into response.

$f_4(R\text{-}Ex)$ is execution of response.

S-S includes conservation, classification, conservation/compression, classification/compression, creation/compression.

S-R includes the same list.

The authors apply it to mathematical operations with a calculator.

The method is too coarse, and the taxonomy too coarse, to be of interest. Perhaps it may have heuristic value for cognitive task analysis.

B. Characteristics of Method

See above. No applicability to operation of large complex systems.

DeVries Jr., P.B., Eickenbrenner Jr., A.J.E., Ruck, H.W. "Task Analysis Handbook"

July 1980. McDonnell Douglas Astronautics, St. Louis, Mo. AD-A087 711.

A. General

1. Source

Aerospace

2. Objectives of the Document

To provide a set of procedures and guidelines for analyzing tasks into sub-tasks and supporting skills and knowledge.

3. Discussion and Recommendations

Designed by subject matter experts for use in technical training for aeronautics and astronautics.

B. Characteristics of the Method

1. Type of Task Analysis

Prescriptive

2. Data Collection Methods

- Examine site (if possible)
- Personal observation
- Interviews with experts

3. Completeness of data

Very detailed

4. Extent of Work

Usually determined by amount of timed instructor has available before training session starts.

5. Resources

Simulator (instructor shows know how it differs from reality)

6. Cooperation

Much between the analyst and expert if different people.

Folley, J.D. Development of an improved method of task analysis and beginnings of a theory of training. NAVTRADEVCEN 1218-1. 1964.

A. General

1. Source

U.S. Navy

2. Objectives of this document

An introduction to the relation of task analysis to the definition of training objectives for U.S. Navy personnel. Some discussion of establishing cost effectiveness. Assumes that the reader is familiar with "Guidelines for task analysis" NAVTRADEVCEN 1218-2.

3. Discussion and Recommendation

Relatively slight document. The more important document is NAVTRADEVCEN 1218-2.

B. Characteristics of the Method

1. Type of task analysis

Prescriptive and Descriptive.

2. Data Collection Methods

Paper and pencil
Manuals
Observation of tasks being performed.

3. Completeness of Data

Probably fairly complete, but see NAVTRADEVCEN 1218-2.

4. Extent of Work

Complete. Assumes trained analysts familiar with Navy tasks and organization.

5. Resources

No special resources required.

6. Cooperation

Assumes usual degree of cooperation expected in military settings.

Gertman, D.I., Blackman, H.S., Gilmore, W.E. & French, D.L. ATR Task and training requirements analysis. EGG-REP-6273. 1983. EG&G Idaho, Inc. Idaho Falls.

A. General

1. Source

Nuclear.

2. Objectives of this Document

Application of questionnaire and rating scales to determine the importance of various tasks for detailed task analysis in connection with a training program for Advanced Test Reactor (ATR).

3. Discussion and Recommendations

Likert scales were used with subject matter experts to rank tasks for their relative importance as choices in task analysis candidates. Lists are provided showing the ranking of the various tasks. Cross reference is made to procedures. The task description chart is considerably larger and more detailed than the General Physics, INPO, or DOE charts. The list of categories, and the list of action verbs should be considered as candidates for the systematic vocabulary required for task analysis. The method described could be used for the purpose of deciding which tasks to submit to task analysis.

B. Characteristics of the Method

1. Type of Task Analysis

Prescriptive - Descriptive.

2. Data Collection Method

- Questionnaires
- Rating scales
- Procedures
- Subject matter experts
- Operators

3. Completeness of Data

Quite complete.

4. Extent of Work

Moderate for this actual phase, with overall effort depending on the number of tasks examined. Probably several man-weeks.

5. Resources

- Procedures
- Table top
- Computer analysis

6. Cooperation

Operators
Subject matter experts
Perhaps some from systems engineers

Gregory, R. Personalized Task Representation. AMTE(E)-TM 79103. 1979. Admiralty Training Establishment, Teddington, U.K.

A. General

1. Source

U.K. Navy

2. Objectives of this Document

The author suggests that in addition to the standard behavioural methods of task analysis it is important to obtain a "phenomenological" or subjective view of the task as seen by the operator. The analyst sees behaviours, actions, etc. The operator sees causes, reasons and context. A task analysis should discover the operator's' 'internal model' of the process being controlled. This will lead to a better understanding of why an operator does what he does. There is an interesting description of how skill develops, explaining how identical observable behaviour can be very different in reality: The novice looks at displays and acts on the controls, but the expert sees the world and carries out the task with the equipment as part of himself.

3. Discussion and Recommendations

This is an interesting idea, especially with respect to response to non-design faults. The method is similar to constructing subjective 'cause-consequence' diagrams. It could be used as a supplement to behavioural task analysis, but cannot be regarded as a primary method for general use. It might be of particular relevance to "paradigming" when inadequate procedures are discovered.

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive

2. Data Collection Methods

- Interview
- Questionnaire

3. Completeness of Data

Specialized addition to supplement standard task analysis.

4. Extent of Work

Requires an experienced interviewer and time to carry out in-depth interviews. Several man-hours to man-days per operator per task.

5. Resources

- Pencil and paper
- Audio recorder

6. Cooperation

Requires cooperation from operators.

Haeger, A. and Stevens, L. "Task Analysis-Based Training Program for Nuclear Engineers." American Nuclear Society Transactions, June 1983, 555N.

A. General

1. Source

Nuclear

2. Objectives of the Document

This report outlines briefly the method for task analysis developed by INPO for Commonwealth-Edison. The method was developed to identify the tasks carried out by unit nuclear engineers. A subsequent analysis of the tasks followed. The focus of the analysis was to:

- determine tasks and performance measures
- choose tasks that will be trained
- develop training objectives
- develop instruction
- implement instruction
- evaluate results and revise program

3. Discussion and Recommendations

This prescriptive method is an example of combining a paper and pencil method with a mini table-top analysis. The method however, lacks a descriptive component where validation of the results can be carried out.

B. Characteristics of the Method

1. Type of Task Analysis Method

Prescriptive

2. Data Collection Methods

- interviews with engineers and supervisors
- procedures

3. Completeness of the Data

Very complete prescriptive data

4. Extent of the Work

Requires a principal analyst with extensive training and experience. Work would take a few months to complete.

5. Resources

No special resources

6. Cooperation

Requires aid from engineers and trainers.

Hinton, W. "F-4AJ/N Instructional Systems Development: Phase I Final Report" Allen Corp.; Orlando, July 1978.

A. General

1. Source

Aerospace

2. Objectives of the Document

The report describes an instructional system used to train F4 AJ/N fighter pilots. The system utilizes a detailed, specific task analysis method to provide accurate procedures for training, and to provide data for job analysis.

3. Discussion and Recommendations

This method of task analysis is designed to provide descriptive data only. The method focuses on operators (pilots) and what they do rather than what they should do. The method is too specific to the application at hand -- training fighter pilots and developing their job guidelines.

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive

2. Data Collection Methods

- interviews with pilots
- questionnaires to pilots
- procedures

3. Completeness of the Data

Incomplete descriptive -- for specific purposes only.

4. Extent of the Work

Requires a principal analyst with some training and long term experience. Job should take from 1 to 2 months.

5. Resources

No special resources

6. Cooperation

Full cooperation is required from pilots and trainers.

Hopkin, V.D. "Human Factors in Air Traffic Control" AGARD-AG-275, 1982. North Atlantic Treaty Organization.

A. General

1. Source

Aerospace

2. Objectives of the Document

This report is a comprehensive guideline for human factors applications within the Air Traffic Control environment. The document contains a section on Task Analysis which describes a descriptive/prescriptive method.

3. Discussion and Recommendations

The method proposed by Hopkin is similar to that described in Van Cott and Kinkade's Guide. The limitations of the method are also similar, in that the analyst must come up with modifications and solutions based on data that represents what operators are already doing, not what they should be doing.

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive - prescriptive

2. Data Collection Methods

- time and event recording
- video and still photography
- personal observation
- flow diagrams and procedures
- biological measures such as eye movement

3. Completeness of the Data

Very complete descriptive but incomplete prescriptive

4. Extent of Work

Requires one or more analysts who have some training and long term experience

This task analysis could take up to six months

5. Resources

- Mock ups
- Video and film equipment
- computer

6. Cooperation

Requires cooperation from:

- operators and supervisors
- system engineers
- training staff

Jenkins, J. "Task Analysis." In The Man-Machine Interface and Human Reliability: An Assessment and Projection. IEEE Conference NUREG/CR-0035, 1981. IEEE, N.Y.

A. General

1. Source

Nuclear

2. Objectives of the Document

This paper provides a suggested method for task analysis to be used in Control Room Design Review for Nuclear Power Plants. The method is derived from the task analysis in which General Physics had been involved at the time. As a result the method is similar to that which was described in NUREG/CR-2895. (See description of NUREG/CR-2895 in this report.)

3. Discussion and Recommendations

The method that Jenkins presents is general and applicable to more than just the NPP control room. It follows the systems approach and should be adaptable to a prescriptive-descriptive method.

Jenkins does not address the specific use of procedures training materials etc. to develop a preliminary task analysis. Since he suggests the use of a systems approach it seems odd that a paper and pencil task analysis is not suggested.

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive with a prescriptive component

2. Data Collection Methods

- Personal observation
- Interview engineers
- Procedures and system plans

3. Completeness of the Data

Descriptive very complete
Prescriptive incomplete

4. Extent of the Work

Large team of analysts with extensive training and experience. Variable time period from few months to over 6 months.

5. Resources

No special resources

6. Cooperation

Operators
Systems engineers

Kidd, S. and Van Cott, H. "System and Human Engineering Analysis". In Human Engineering Guide to Equipment Design by Van Cott, H. and Kinkade, R. (eds.). Washington; American Institute of Research. 1972.

A. General

1. Source

Textbook

2. Objectives of Chapter

This chapter describes two methods of task analysis that, combined, allow for the development and planning of effective designs. The authors propose that a descriptive analysis be done first. Then the data should be subjected to a time-line analysis. This subsequent analysis provides the analysts with information regarding:

- peaks in workloads
- conflicts in demands on personnel and equipment;
- other requirements not apparent from the descriptive analysis

The authors indicate that use of the two methods allows a two step approach. First the analyst describes the tasks, then he must examine the tasks in the context of time relationships, communications (information flow), equipment etc.

3. Discussion and Recommendations

Kidd and Van Cott suggest an opposite approach to what appears to be pervasive in the nuclear field. Instead of the development of a working model from a prescriptive task analysis they propose that they first collect data through a descriptive observational approach. Hence, the authors appear to expect that the data will indicate problems and will suggest modifications. This understanding is expected to occur through time-line, error and contingency analysis. The results of these analyses will allow the analysts to prescribe the best system.

B. Characteristics of the Method

1. Type of Method

Descriptive and Prescriptive

2. Data Collection Methods

- Personal observations
- Written procedures

3. Completeness of the Data

Descriptive and prescriptive mostly complete

4. Extent of the Work

Requires a principal analyst with extensive training and experience. No time frame is indicated

5. Resources

No particular resources other than written procedures, systems plans, etc.

6. Cooperation

Requires aid from design and systems engineers.

Meister, D. Human Factors: Theory and Practice. New York; Wiley, 1971.

A. General

1. Source

Textbook

2. Objectives of the Chapters

Meister describes the role of task analysis in planning and in detailed design. He stresses the systems approach to task analysis whereby the analyst begins with a prescriptive model. This model is illustrated in an operational sequence diagram (OSD) which is used as a tool to organize functions, tasks and subtasks into a time-line. Subsequent descriptive analysis (observations, walkthroughs etc.) can then be used as confirmation of the proper sequencing and relationships between tasks.

3. Discussion and Recommendations

The method is described in a general way, so that it may be used for all human-machine systems. This generality in the method allows it to be adaptable though applying it to a specific system requires knowledge and experience.

Further, this method is similar to and in fact may be the precursor to, many of the methods of task analysis found in the recent literature. The method is referred to, for instance, by Jenkins (NUREG/CP-0335 -- see also the annotation for that paper). The systematic approach of this task analysis method is most appropriate to the NPP control room context.

B. Characteristics of the Method

1. Type of Task Analysis

Prescriptive with a descriptive component

2. Data Collection Methods

- Procedures and systems plans
- Video and Film
- Questionnaires and interviews with experts and operators

3. Completeness of Data

Very complete prescriptive and descriptive

4. Extent of the Work

- Requires one or more analysts with extensive training and experience. Method would take a few months to complete.

5. Resources

- video and film equipment
- simulator
- computer

6. Cooperation

Requires the aid of systems engineers, operators and supervisors.

Merrill, M.D., Reigelluth, C., Branson, R.H., Tarr, R., Begland, R. "Extended Task Analysis Procedure (ETAP): Training Materials Orientation Lesson: Introduction to ETAP." AD-A098 389. 1980. Army Training Development Institute, Fort Montroe, Va.

A. General

1. Source

Military

2. Objectives

The paper designed to introduce a student to ETAP. Upon completion, the student should understand the ETAP and be ready to practise using the user's manual.

3. Discussion and Recommendations

The paper introduces the ETAP procedure in 8 lessons for the student, which include many sample "conversations" between and "analyst" and an "expert" int he job being analysis. The paper seems designed for use by those with little or no background in task analysis.

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive

2. Data Collection Methods

- written procedures
- Interviews with experts

3. Completeness of Data

no data collected

4. Extent of Work

Varies with procedure to be analyzed, usually 1 researcher.

5. Resources

None recommended.

6. Cooperation

Much time spent with experts.

Meyer, R.P., Leveson, J.J., Pape, G.L., Edwards, B.J. "Development and Application of a Task Taxonomy for Tactical Flying. Vol I-III."

Sept. 1978
Vol. I AD-A061 387
Vol. II AD-A061 388
Vol. III AD-A061 478
Design Plus, St. Louis Mo.

A. General

1. Source

USAF

2. Objectives of the Document

The document describes the development and use of a system of classification rules and now those rules were applied to generate a taxonomic system in a data matrix form, and applying the taxonomy to a range of training problems and questions. 16 representative tactical tasks were chosen, and "talked through" with experienced pilots, co-pilots, and weapon officers. This gave the data base necessary for the task taxonomy.

3. Discussion and Recommendations

Paper is detailed and tells how to set up a surface task analysis like one of sixteen representative tactical tasks. The method requires a data base of representative tasks. Many data are reported.

4. Characteristics of the Method

1. Type of Task Analysis

Descriptive

2. Data Collection Methods

- Written Procedures (minor)
- Interviews with Expert (major)

3. Completeness of Data

Very complete, detailed.

4. Extent of Work

4 Analysts; lengthy time.

5. Resources

"Talk-through" simulation only.

6. Cooperation

Required approximately 40 pilots, co-pilots and weapon officers.

Miller, R.B. A method for man-machine task analysis. WADC-TR-53-137. 1953. Wright Air Development Center, Wright-Patterson Air Force Base, Dayton, Ohio.

A. General

1. Source

U.S. Air Force

2. Objectives of this Document

This is the original definition and description of classical 'task analysis' by its originator. A classic document.

3. Discussion and Recommendations

Should be read for historical interest, in order to understand the intentions of the original designer. The emphasis was on task analysis for training. But in addition the author states the following, which admirably summarizes the importance of task analysis for design. "... this procedure can, with some limitations, be used to forecast a job before any operator has ever performed that job. The analysis can be just about as complete and accurate as design engineers are able to forecast the operating characteristics of the equipment they are developing."

The conciseness of this original description is a good preparation for reading more modern versions. The question of validation is well discussed: the task

analysis description should enable a novice to carry out the task correctly in all respects.

B. Characteristics of the Method

1. Type of Task Analysis

Prescriptive and Descriptive

2. Data Collection Methods

- Procedures
- Observation of task
- Equipment
- Pencil and paper, Table top

3. Completeness of Data

Intended to be complete

4. Extent of Work

Requires a well trained analyst with access to all manuals, hardware, operators, etc.

5. Resources

Very little other than paper and pencil recording materials.

6. Cooperation

Requires cooperation from operators, designers, and procedure writers.

Nordic Liaison Committee for Atomic Energy "Technical Summary Report on Control Room Design and Reliability." Enlarged Nordic Cooperative Program on Nuclear Safety. NKA/KRU-(81)13, 1982.

A. General

1. Source

Nuclear

2. Objectives of the Document

The report describes methods that can be used to improve the design process and improve the reliability of the control room system of a nuclear power plant. The report "summarizes the problems, studies and results ..." for the following areas:

- operator models and behaviour
- operator attitude
- criteria for human-machine interaction
- possibilities for computer-based operator support
- experimental methods of validation

3. Discussion and Recommendations

The task analysis method described in this document is considered to be appropriate to the modern automated control systems in nuclear power plant control rooms. The method concentrates on developing models of behaviour, particularly for information processing. The form of analysis used was called "situational analysis."

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive-prescriptive

2. Data Collection Methods

- Personal observation
- Interviews with experts and operators
- Use of flow diagrams

3. Completeness of Data

Incomplete descriptive
Incomplete prescriptive

4. Extent of the Work

Variable -- description is too vague to determine human resources or time

5. Resources

No special resources

6. Require aid of - operators
- supervisors
- trainers

NUTAC. Human Engineering Principals for Control Room Design Review. INPO 83-036 (NUTAC) 1983. Institute of Nuclear Power Operations, Atlanta, Ga.

A. General

1. Source

Nuclear

2. Objectives of this Document

Provides a glossary and dictionary of terms and language used in human factors efforts applied to nuclear power production, explaining all terms as they are used to define a principle of good human factors practice.

3. Discussion and Recommendations

This document is an excellent source document for anyone entering the field of the application of human factors to nuclear power engineering. It should be a standard reference. Unfortunately it is proprietary to INPO who are extremely resistant to releasing it for use or even examination by non-INPO members.

B. Characteristics of the Method

This section is not applicable to this document.

NUTAC. Control room design review task analysis guidelines. INPO 83-046 (NUTAC) 1983. Institute of Nuclear Power Operations, Atlanta, Ga.

A. General

1. Source

Nuclear

2. Objectives of this Document

To provide a detailed guide as how to carry out a prescriptive task analysis as required by NUREG-0700.

3. Discussion and Recommendations

This is the second best account of how to carry out a prescriptive task analysis. (Second only to DOE/EP-0095). It describes the main techniques and provides examples. It does not include a discussion of how to set up a computerized data base for using the data acquired. It does not deal with problems specific to "advanced" control rooms. It is an excellent document which unfortunately is proprietary. INPO is extremely unwilling to release it for use or examination except to member organizations.

B. Characteristics of the Method

1. Type of Task Analysis

Prescriptive

2. Data Collection Methods

Questionnaire
Interview
Table top
Procedures
Talk through/Walk through
Simulator

3. Completeness of Data

Complete

4. Extent of Work

Requires trained task analysts for several man-months.

5. Resources

Total system plus simulator and all personnel.

6. Cooperation

Operators
Engineers
Supervisors
Designers
Trainers
Management
Subject matter experts

Parks, D. and Springer, W. Human Factors Engineering Analytic Process Definition and Criterion Development for CAFES" CAFES VOL I report D180-18750-1. January 1976, Seattle, Boeing Aerospace.

A. General

1. Source

Aerospace

2. Objectives of the Document

This study set out to develop an approach and a set of procedures in order to provide human factors engineering analyses appropriate to CAFES. The procedures were designed to allow the construction of computer models and a computerized data base.

Within this system is included a method of task analysis which was designed to make sure that the requirements for tasks are met, and to ensure that no problems exist in the allocation of tasks to crewman, that crewmen may carry out tasks at a given level of performance and that enough time is available to carry out the task.

3. Discussion and Recommendations

The method is prescriptive with some descriptive data being collected to both validate the prescriptive analysis and to augment it. Hence, the method is somewhat flexible and allows missing data such as performance time for tasks, error probabilities, proper sequencing etc. to be added.

The method utilizes simulators, computers and mock ups to collect data needed to augment prescriptive data. This task analysis method is well suited to the rigid structure of the tasks that are to be carried out by crewmembers of aircraft. Most of the contingencies and problems they must deal with can be anticipated. Such anticipation of events can not always be accomplished in the complex, variable nature of emergency scenarios that exist in the nuclear power plant control room. Therefore, this method would require more latitude in the flow diagrams and time-lines so that many alternative pathways may be followed.

B. Characteristics of the Method

1. Type of Task Analysis

Prescriptive-descriptive

2. Data Collection Method

- Personal observation
- Procedures and documented guidelines
- Systems plans

3. Completeness of Data

Mostly complete for prescriptive and descriptive data.

4. Extent of the Work

Requires a team of analysts with training and experience. Can be carried out in a short time (a few weeks to 2 months) since many analysts can work together.

5. Resources

- Simulator
- Computer
- Mock ups

6. Cooperation

Some from system engineers.

Piso, E. "Task Analysis for Process-Control Tasks: The Method of Annett et al. Applied" Journal of Occupational Psychology. Vol 54(4) 247-254.

A. General

1. Source

Industrial Manufacturing

2. Objectives of the Document

This report describes a method of task analysis carried out in a glass factory. The analysis was undertaken in order to improve the process control system. Thus the method was used to find out how the operators controlled the processes of glass manufacture. This information was then used to design a semi-automated system.

3. Discussion and Recommendations

The approach is mostly prescriptive using flow diagrams to construct stimulus-operation-response models. These models are then used to formulate questions about goals, durations of activities, conditions, problems, and how often activities occur.

The method does not, however, include a descriptive component to validate the resulting design guidelines.

B. Characteristics of the Method

1. Type of Task Analysis

Prescriptive

2. Data Collection Methods

- Interviews with operators and trainers
- Procedures and system plans

3. Completeness of the Data

complete prescriptive

4. Extent of the Work

Requires two analysts (process and task) with extensive training and experience.

Method could take a few months to complete.

5. Resources

no special resources

6. Cooperation

Require aid of operators and trainers.

Price, H. and Van Cott, H. "A Human Factors Needs Assessment and Planning Study". AECB INFO-0084, 1982. Biotechnology.

A. General

1. Source

Nuclear

2. Objectives of the Document

The report outlines the human factors needs that the AECB should consider in CANDU nuclear plants. The document includes a section on task analysis. This analysis has been designed to provide task data for design, development and review purposes.

3. Discussion and Recommendations

The method for this task analysis parallels the method developed by General Physics and Biotechnology (NUREG/CR-3371). There is a great deal of emphasis on the descriptive rather than prescriptive. The data collection and the subsequent suggested analyses reflect this bias.

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive with some prescriptive

2. Data Collection Methods

- procedures and systems plans
- walkthrough/talkthrough
- interviews with operators
- video tape records
- simulator - PMS

3. Completeness of the Data

descriptive is complete
prescriptive is incomplete

4. Extent of the Work

Requires a large team of experts and well trained personnel. The method would take 5 - 6 months to complete.

5. Resources

- simulator
- computer
- video equipment

6. Cooperation

Require help from most personnel involved in the control room.

e.g. - operators and supervisors
- training staff
- technical support staff

Reed, L.E. Advances in the Use of Computers for Handling Human Factors Task Data. AMRL-TR-67-16. 1967.

A. General

1. Source

U.S. Army

2. Objectives of the document

To define data types for use in setting up a data base to handle task analysis data and to discuss how to organize such a data base for ease of use.

3. Discussion and Recommendations

Task analysis is "an analytical process employed to determine the specific behaviours required of human components in a man-machine system ... on a time base the detailed performance ... of man and machine .. then interactions ... behavioural steps are isolated, in terms of their perceptions, decisions, memory storage, and motor outputs required, as well as the errors which may be expected."

The process of task analysis is described, showing the various categories into which the data may be classified. Forty-five types of data from task analyses are listed, which may be narrative reports, formatted data, flow diagrams, or sketchs, drawings or charts. Emphasizes the need for a standard vocabulary if results are to be generalized across systems, and the importance of modelling and simulators. Gives several references to earlier papers on recording and data

handling methods.

This paper is not, strictly speaking, about task analysis methods as such, but on how to handle the data. Its main relevance is to the data base design.

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive for task, Prescriptive for training

2. Data Collection Methods

Not relevant. Thhe paper is concerned with the classification of data however it is collected.

3. Completeness of Data

As complete as the method supplying data.

4. Extent of Work

Not relevant.

5. Resources

Computer
(Note that technology has changed considerably in a direction which will make data handling easier).

6. Cooperation

Task analysts
Computer Staff

Reigeluth, C.M., Branson, R.K., Begland, R., Tarr, R., and Merrill, M.D. "Extended Task Analysis Procedure (ETAP). User's Manual." 1980. AD-A048 351. Syracuse University, N.Y.

A. General

1. Source

Military

2. Objectives of the document

ETAP is designed to analyze primarily procedural tasks, so-called "soft-skill" tasks. The manual is designed to aid an analyst performing an ETAP.

3. Discussion and Recommendations

ETAP is designed to identify the skills and knowledge needed to master a task. It consists of 3 phases: Process Analysis, Substep Analysis, and Knowledge Analysis. Process Analysis identifies each step in a procedure, with the help of a flow chart. Substep Analysis is used to determine the substeps which make up each step. Knowledge Analysis determines the prerequisite skills and knowledge necessary to perform the task.

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive

2. Data Collection Methods

- Written procedures
- Interviews with experts

3. Completeness of Data

- Very complete when used.

4. Extent of Work

Depends on number of jobs to be analyzed, but requires at least one analyst, who should have training and experience.

5. Resources

Simulation is possible but unlikely, since "soft-skill" jobs are usually inappropriate for simulation studies.

6. Cooperation

Requires analysts to spend time with an expert in the procedure for long enough to be certain the procedure is analyzed sufficiently. Usually no involvement with the person performing the procedure unless he is also the expert.

Swain, A.D. and Guttmann. "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications." NUREG/CR-1278, 1983. Sandia.

A. General

1. Source

Nuclear

2. Objectives of the Document

This report is a handbook for carrying out human reliability studies in nuclear power plants. The handbook contains a section on task analysis which describes the method and its applications. Since the handbook is a guide to performing analyses related to the reliability of the whole nuclear power plant system, whether it be existing or proposed, the handbook outlines a descriptive-prescriptive approach to task analysis. This combined approach allows the analyst to first determine what the operators should do, then find out what they are doing.

3. Discussion and Recommendations

The authors indicate that much of the method for the task analysis has been borrowed from the task analysis described in NUREG/CR-2254. The method they suggest, however, incorporates the military approach whereby task data is collected as 1) descriptive and 2) analytical. As a result the data may be used for mere descriptive or for analytical purposes, or a combination of both. That is if only descriptive information such as frequency, duration, activity or instrument is required for a subsequent analysis (e.g. Link) then the first form can be used. If, however, error analysis, cognitive skill assessment or assessments of task difficulty or efficiency are to be analyzed, a more comprehensive analysis data form may be used.

The objective of the section on task analysis is to provide a flexible method that will allow analysts to adapt the method to their needs.

B. Characteristics of the Method

1. Type of Task Analysis

Prescriptive/Descriptive combined method

2. Data Collection Methods

- personal observation
- procedures and system plan
- walkthrough/talkthrough
- interviews with subject matter experts and operators

3. Completeness of the Data

very complete descriptive data
incomplete prescriptive data

4. Extent of the Work

Requires a principal analyst with extensive training and experience. The method would require about 4 to 5 months to complete.

5. Resources

Mock up (for walkthrough/talkthrough)

6. Cooperation

Some help from operators and trainers, as well as systems personnel.

von Herrmann, J. "Methods for Review and Evaluation of Emergency Procedure Guidelines: Methodologies." NUREG/CR-3177, 1983. Idaho National Engineering Laboratory.

A. General

1. Source

Nuclear

2. Objectives of the Document

The research describes methods in the review and evaluation of written emergency procedures developed for existing and new systems. The author stresses the change in focus from the event-oriented procedural approach that characterized NPP before Three Mile Island, to a function-oriented approach that has emerged recently.

The document outline the methods of procedures development used by the major owners group programs. The methods are based to some degree on the newer function-oriented rather than event-oriented approach. This shift to function-oriented diagnosis of problems and structuring of the written procedures for emergency situations, means more emphasis on tasks and subtasks.

3. Discussion and Recommendations

The author stresses a prescriptive approach to task analysis, stating that "there is a limited set of key safety functions which if successfully performed automatically or through manual action, result in a 'safe' condition for the plant." The prescriptive method can help to identify the "key safety functions which ... result in a safe condition", whereas the descriptive approach would merely indicate what practices were operating at present. These practices may not be the best to promote a "safe" condition for the plant.

B. Characteristics of the Method

1. Type of Task Analysis

Prescriptive

2. Data Collection Methods

No information about data collection method appears to be given

3. Completeness of Data

Incomplete prescriptive and descriptive data

4. Extent of the Work

Requires a principal analyst with extensive training and experience. Job should take 2 to 3 months.

5. Resources

No special resources mentioned

6. Cooperation

Requires aid of design engineers and systems engineers

Walton, B.L. and Begland, R.R. Job and Task Analysis Handbook. TRADOC-PAM-351-4(T). 1979. Army Training and Doctrine Command. Fort Monroe, Va.

A. General

1. Source

U.S. Army

2. Objectives of this Document

This pamphlet is a user's guide to job and task analysis to be used after taking the appropriate TRADOC training course. It "assumes completion of the job training package."

3. Discussion and Recommendations

Very thorough and detailed, but to a considerable extent shaped by application to the military context. "... the novice should not be expected to perform, conduct or understand the entire process after going through the materials and reading this handbook ... (proficiency) requires time and experience on the job as an analyst." This comment alone makes the document worth reading. The main thrust of this document is towards the use of job and task analysis in training. But in order to identify training requirements the skills and knowledge needed, operator motivation, characteristics of the environment, and equipment need to be specified. They note that a comprehensive task analysis may produce results which have an impact on training, equipment, management practice, job structure, career structure and recruitment criteria. Several estimates are given (for specific task analysis) of the time and labour required. These are all of the order of 6 to 9 months and up to 80 man-months. The authors emphasize that task analysis is resource intensive and must be restricted to the most urgent matters. For the same reason it is most cost effective if incorporated very early in the design process and used iteratively, as shown in the following figure.

Analyze Design Develop Train Evaluate

They include a number of rating scales which help the user to identify the most critical tasks, and suggest that eight main dimensions are relevant: per cent of people performing the task; per cent time spent performing the task; consequences of inadequate performance; task delay tolerance; frequency of performance; difficulty of learning the task; probability of deficient performance; immediacy of performance. Very detailed discussions of applications to various tasks of the military, which show, in the appendices, how varied the outcomes of a task analysis may be for different "industries". Very detailed discussion of methods, terminology, etc. Good discussion on cost effectiveness.

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive - Prescriptive

2. Data Collection Methods

- Perform the task
- Observe the task
- Interviews with operators
- Literature review
- Subject matter experts
- Consult supervisors

3. Completeness of Data

Very complete. Method also contains detailed warnings about possible pitfalls (e.g. observation is a limited sample and may not be an adequate sample for descriptive task analysis: some behaviour may not be observable.)

4. Extent of Work

Assumes extensive task analysis personnel who are fully trained. All "operators" and analysts are assumed always to be available. Estimates of man-weeks and total duration given in several cases.

5. Resources

Military personnel, military equipment, etc. assumed "ad lib" within a reasonable time frame of several months.

6. Cooperation

Assumed complete as required because of military setting.

Wilson, D. Application of Automatic Data Processing Techniques to Task Analysis Diagramming. NPRA SRM 68 8, 1967. Naval Personnel Research Laboratory, San Diego.

A. General

1. Source

U.S. Navy

2. Objectives of this document

A method is described by which graphical descriptions of task analysis similar to operation sequence diagrams can be used or input to a computer.

3. Discussion and Recommendations

It is doubtful whether the graphical method described is capable of capturing the finest levels of detail, but it is difficult to be sure. The technique described uses out of data technology, and it is probable that more modern menu-driven systems with mouse pointers, etc. would make the technique more effective. It could be a topic for a small research contract, but does not immediately offer a marked improvement over conventional taxonomies.

B. Characteristics of the Method

1. Type of Task Analysis

Prescriptive - Descriptive

2. Data Collection Method

Any -- followed by transcriptions of symbols to computer readable form.

3. Completeness of Data

Not relevant -- depends on completeness of task analysis used.

4. Extent of Work.

Not relevant -- depends on completeness of task analysis used

5. Resources

Computer

6. Cooperation

Task analysts
Computer staff

Woodson, W. Human Factors Design Handbook. New York; McGraw-Hill, 1981.

A. General

1. Source

Handbook

2. Objectives of the Chapter

The chapter on System Analysis describes a task analysis method that will provide data for the following analyses:

- to determine task criticality
- to indicate problem tasks
- to determine task duration and sequencing of tasks
- to determine task difficulty

3. Discussion and Recommendations

None

B. Characteristics of the Method

1. Type of Task Analysis

Descriptive

2. Data Collection Methods

- Personal observation
- Interviews with operators and experts

3. Completeness of the Data

Complete descriptive

4. Extent of the Work

Requires an analyst with extensive training and experience. Variable time period.

5. Resources

No special resources indicated

6. Cooperation
Requires aid of operators and trainers.

11.0 GLOSSARY

Action Verbs: A list of verbs to be used in task analysis. Only these verbs may be used in the Task Data Form, and the list must include enough verbs to cover all behaviour which is found. The verbs must be mutually exclusive.

"Advanced" Control Rooms: Any control room in which extensive use is made of computer generated displays and computerized control interfaces, rather than traditional hard-wired displays and controls.

AECB: Atomic Energy Control Board.

AGARD: Advisory Group for Aerospace Research and Development, NATO.

Berliner Taxonomy: A task taxonomy popular in nuclear human factors.

CAFES: A computerized engineering design guide developed by the Boeing Aircraft Corporation, Seattle, U.S.A.

Cognitive activity, behaviour: Human information processing involving thinking, reasoning, problem solving, decision making or memory.

CRDR: Control Room Design Review.

CRT: Cathode Ray Tube.

DCRDR: Detailed Control Room Design Review.

Descriptive Task Analysis: A task analysis which identifies the behaviour actually used by operators to perform tasks whether or not their methods are those described by operating procedures.

DOE: Department of Energy (U.S.A).

DTA: See Descriptive Task Analysis.

Element: An identifiable unit of behaviour which is not meaningful except as part of a task. The finest level of detail in a task analysis.

EOP: Emergency Operating Procedures.

EPRI: Electric Power Research Institute.

HRA: Human reliability analysis. The examination of the effect on system reliability of the human component of a human-machine system.

INPO: Institute of Nuclear Power Operations (Atlanta, Ga., U.S.A.)

Job Analysis: A list of all tasks required of a person holding a particular job.

Link Analysis: A method for summarizing the movements of operators from place to place and component to component when carrying out a task. It is often in the form of

transition graphs or transition matrices.

Motor Skills: Skilled movements by humans.

NPP: Nuclear Power Plant.

NRC: Nuclear Regulatory Commission (United States).

NUREG, NUREG/CR: Documents published by U.S. NRC.

NUTAC: Nuclear Task Action Committee of the Institute of Nuclear Power Operations.

Paradigming: A systematic method for creating operating procedures when a situation is found during a task analysis where operators have evolved behaviour in the absence of written operating procedures.

Performance Measurement System: A (computerized) system whereby all plant variables, control states, and display states are continuously recorded during operation of a plant or simulator with a view to collecting as complete data as possible of the behaviour of operators and its effects on the plant. Note that the PMS will not record cognitive activities.

PMS: See Performance Measurement System.

Prescriptive Task Analysis: A task analysis which identifies from system design specifications and operating procedures what operators should do to carry out a task.

PTA: See Prescriptive Task Analysis.

Reliability: A measure of the extent to which a method of measurement gives the same outcome when used repeatedly by a single person or by several people on a single task.

SEEK: A task analysis data base developed by General Physics Inc. for the U.S. nuclear industry under NRC sponsorship.

SME: Subject Matter Expert.

Supervisory Control: A control system in which the majority of control is exercised by a sophisticated computer rather than by the operator manually controlling the process. The human's role is to "supervise" the sophisticated control computer and to intervene only when automatic control fails.

TA: Task analysis.

Tabletop Task Analysis: A task analysis making use of manuals, documents, blueprints, interviews, etc. rather than observations of the operators in a simulator or real control room.

Task: A unit of behaviour required by a job, identifiable as a meaningful unit, with a well-defined beginning and end.

Task Data Form: A form specially created to collect task analytic data in a systematic way.

Task Taxonomy: A systematic classification scheme for describing behaviour observed in tasks.

TDF: See Task Data Form.

THERP: Technique for Human Error Rate Prediction, developed by Swain and others at Sandia National Laboratories.

Time Line Analysis: A method for determining the probability that an operator will have to carry out two or more incompatible tasks simultaneously. Used to estimate operator workload.

TT Task Analysis: See Tabletop Task Analysis.

Validity: The extent to which a measuring system actually measures what it claims to measure.

Walkthrough/Talkthrough: A method of task analysis in which the operators give a running commentary on their actions while carrying out a task in a simulator or real control room.

WTTT: See Walkthrough/Talkthrough.

12.0 ACKNOWLEDGEMENTS

Our thanks are due to the Electric Power Research Institute, Palo Alto, Ca.; and to the U.S. Nuclear Regulatory Commission, Washington, D.C., and to the U.S. Department of Energy, Washington, D.C., for permission to quote and reproduce material, where acknowledged in the body of this report.

Appendix I: EXAMPLE OF "PARADIGMING" IN TASK ANALYSIS.

(From DOE/EP-0095)

PARADIGMS OF ABNORMAL AND EMERGENCY TASKS

Purpose

Straightforward procedural tasks are those that contain routine operations. These tasks are analyzed by TA/SME teams working directly from the task analysis data collection forms as described in Chapter 2. More complicated tasks involving non-routine decisions or extremely complex decision making require a modification of the task analysis methodology called "paradigming".

Paradigming is required for some abnormal and emergency tasks in order to identify adequately the sequence of steps the operator uses in completing these tasks. Paradigming is necessary for abnormal tasks because abnormal tasks are developed from the "Problem Assessment" and "Problem Resolution" blocks of the task analysis sheets and thus do not have established procedures from which the SME can base the necessary task analysis information. Paradigming is necessary for emergency tasks because past experience has shown that some emergency tasks lack procedures of sufficient detail to consider sufficient options available to the operator based on the various dynamic conditions that exist during the course of a plant emergency.

The use of paradigming permits good curricula, good test items, and good objectives to be easily derived in the development of a training program. It is also extremely valuable in developing scoreable units for performance tests in a performance-based training program.

Definition and Elements of Paradigming

Paradigming is the technique used to transfer a narrative task description into a stimulus-response table similar to Figure B-2. Information from this table is then transferred to the task analysis data collection form. The technique of paradigming is based on a number of methods of describing behavior:

1. Stimulus-Response

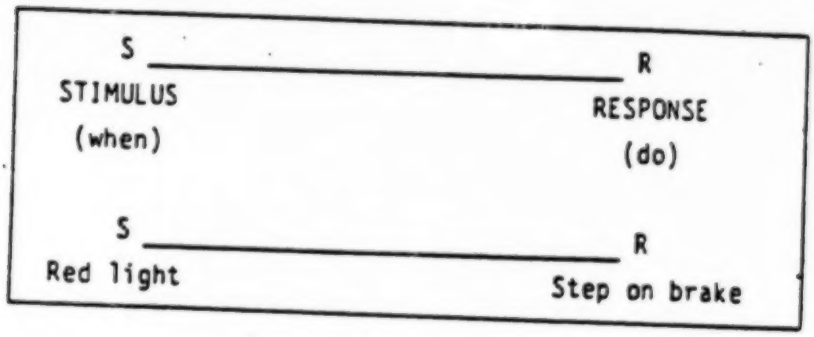
   A paradigm is similar to a flowchart. To paradigm a task means to break the task down into stimulus-response terms ("see green

Task: "Reactor coolant pump motor malfunction"

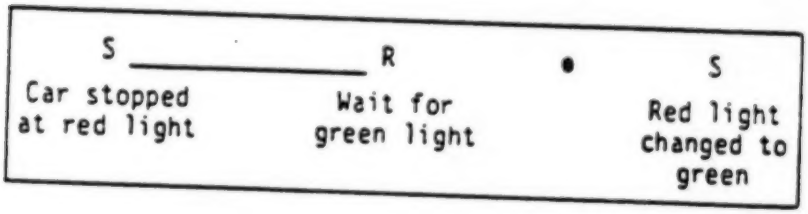
		S2.1 RCP upper bearing temperature higher than max. temp. limit	R2.1 Trip reactor	S3.1 Reactor trip indication due to manual trip	R3.1 Trip affected RCP	S4.1 RCP indicates tripped	R4.1 Inform SS that affected RCP is tripped	End
				S3.2 RCP lower bearing temp. higher than max. temp. limit	R3.2 Go to R2.1	S4.2 RCP motor temp. higher than max. temp.	R4.2 Go to R2.1	
S1.1 RCP or upper/ lower reservoir high/low annunciator alarm	R1.1 Observe RCP upper bearing temp. using plant computer	S2.2 RCP upper bearing temperature normal	R2.2 Observe RCP lower bearing temp. using plant computer	S3.3 RCP lower bearing temp. normal	R3.3 Observe RCP motor winding temp. using plant computer	S4.3 RCP motor temp. normal	R4.3 Direct PEO to visually inspect RCP upper and lower oil reservoir levels	Cont.
				S3.4 RCP lower bearing temp. >normal but <max. temp.	Cont.	S4.4 RCP motor temp.> normal but <max. temp.	R4.4 Place RCP motor temp. on trend using plant computer	Cont.
		S2.3 RCP upper bearing temp.> normal but <max. temp	R2.3 Place RCP upper bearing temp. on trend using plant computer	S3.5 RCP upper bearing temp. increasing or steady	R3.5 Direct PEO to visually inspect RCP upper and lower oil reservoir levels	Cont.		

Example Stimulus-Response Table

light--push auto accelerator"). A stimulus tells the performer "when" to do something; it is part of the performer's environment. A response is what the performer does because of the stimulus; it is the performer's action, either overt (that which can be seen) or covert (mental responses that cannot be observed).



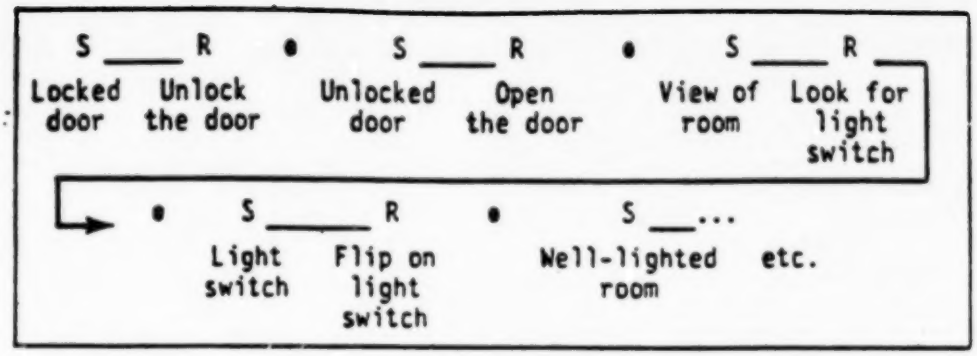
Once the performer does something, the environment changes. When the environment changes, the performer has a new stimulus.



The "•" means "produces" or "results in."

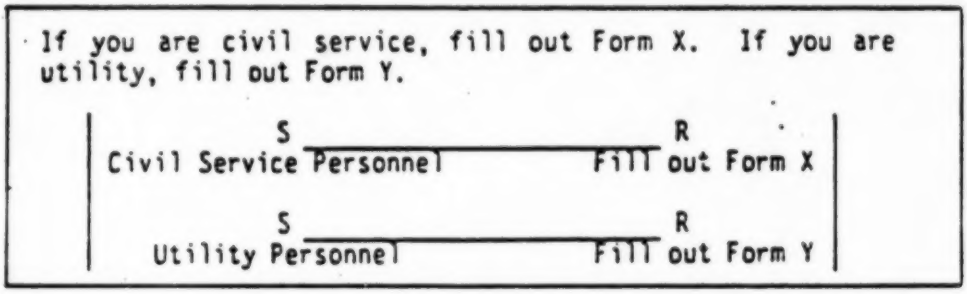
2. Chains

Often the new stimulus calls for another response, resulting in a series or chain or behaviors. In the example below, the chain is a sequential procedure which requires no decision making.



3. Discriminations

Sometimes chains have decision-making behaviors (called discriminations) that have to be made somewhere in the sequence. A discrimination is two or more stimuli that cause different responses.



4. Generalizations

Another type of behavior is a generalization, which is two or more stimuli which call for the same response.

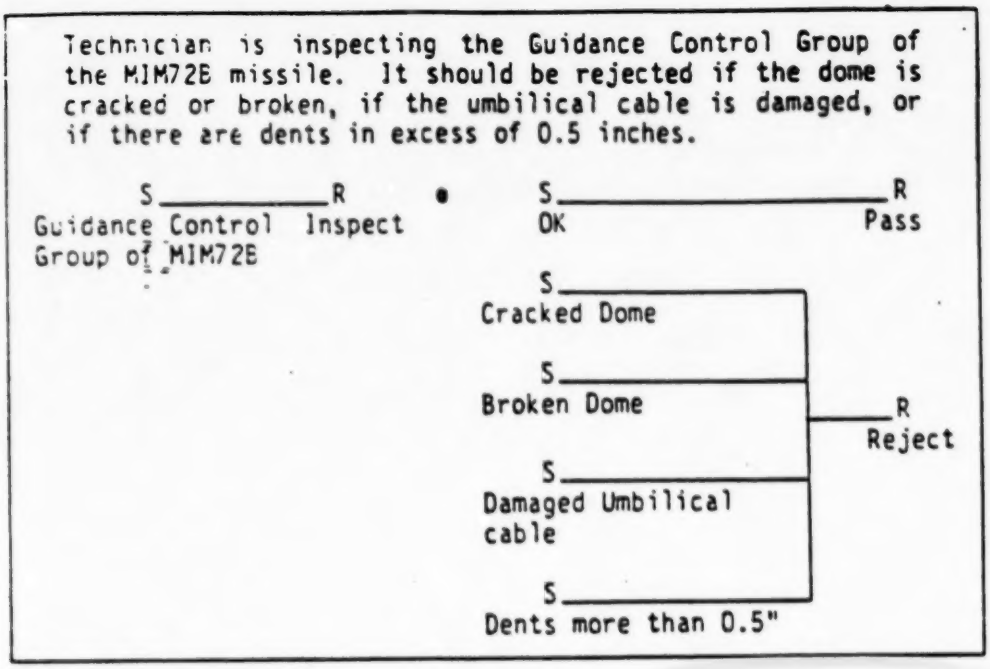


Figure summarizes how a paradigm describes the above-mentioned types of behavior. Any combination of these types may be found in a paradigm of a task. However, whenever possible, the tasks should be broken down into simple chains for simplicity, ease of handling, and the least possibility of error in charting the action flow. Discriminations may be used where needed, but generalizations should be eliminated if possible.

Paradigming Process

A preliminary discussion about the selected tasks between the two team members sets the plant conditions (e.g., shutdown, refueling, startup, etc.) and the system conditions (e.g., all safety sytems lined up and operational) before the start of the paradigm. The initial discussion also includes the identification of the initial stimulus (this is usually the hardest one to determine) that starts the process.

The TA and SME then use the stimulus-response routine described in Section B.5.2 to work their way through the assigned task. Sometimes it is easier to set down the first response (R1) and then work back to determine the first stimulus (S1). This is only for the first stimulus-response. The following ones will be established through the natural flow of the task. This stimulus-response approach not only identifies the obvious operator

A PARADIGM describes behavior in stimulus-response (S-R) terms. A STIMULUS in the environment causes the performer to do something. What the performer does is called the RESPONSE. A paradigm can consist of:

CHAIN

S____R • S____R • S____R • S____R • S____R

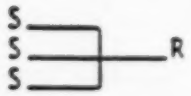
OR

DISCRIMINATION

S____R
S____R
S____R
S____R

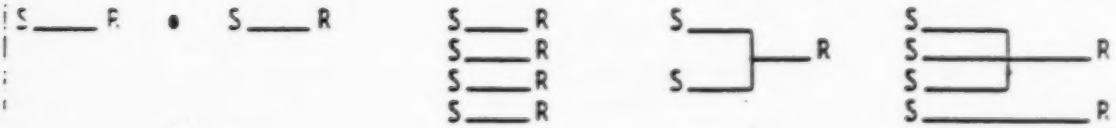
OR

GENERALIZATION



OR

A COMBINATION



Summary of Types of Paradigms

actions but also brings to light the mental thought process performed by the operator. These mental thought processes are covert actions that the operator uses to make decisions based upon his knowledge and experience. These are the hidden skills that must be identified in order to fully train new operators in the performance of various tasks. These hidden skills may seem overly simple, but a complete training program cannot be designed

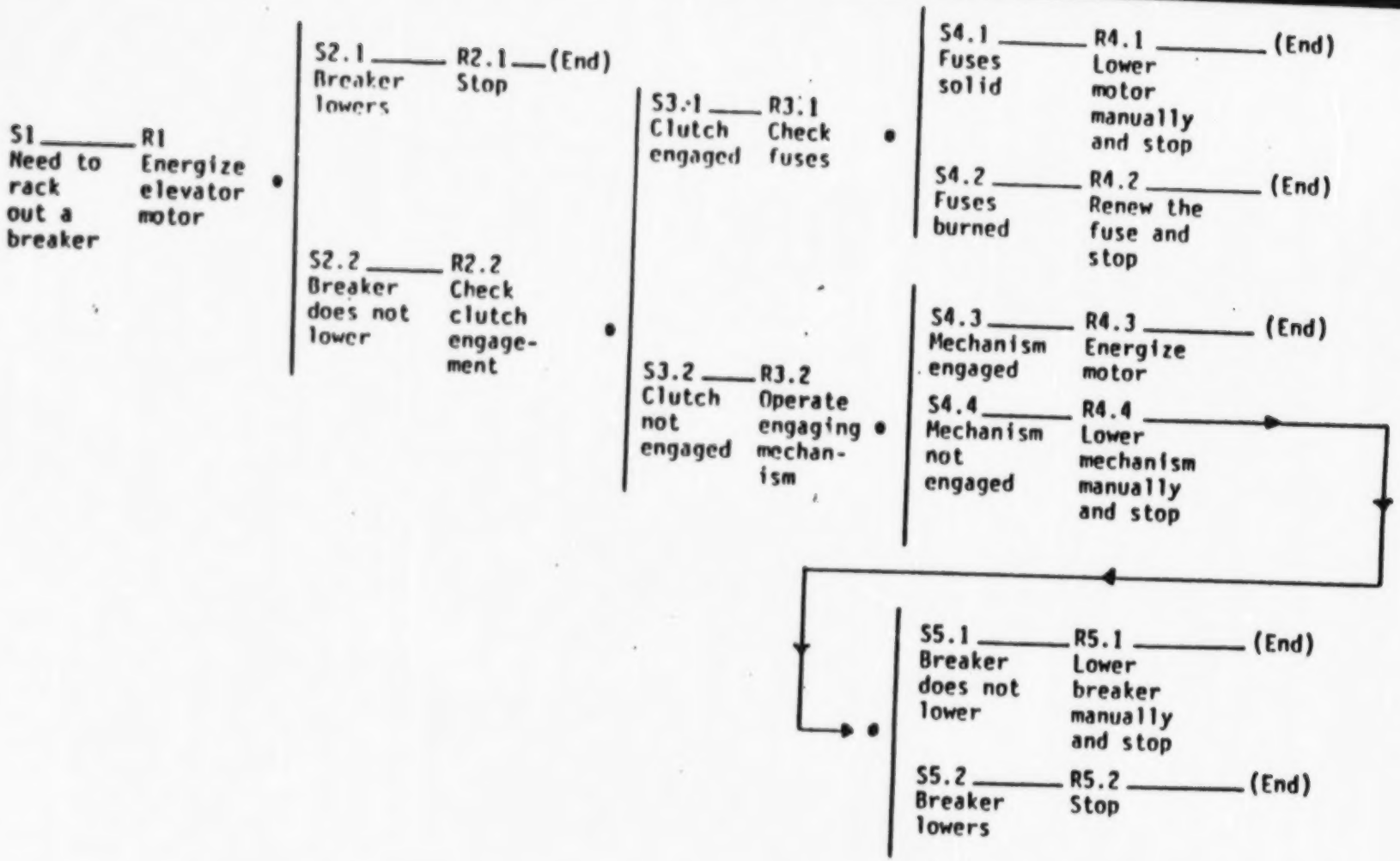
without exploring them. (Examples of covert skills are what the operator sees, hears, smells, tastes, or touches to make a decision.)

On the first task analysis sheet, the TA writes the task title and assigned task number in the space provided and fills in the names of the TA/SME team. Next, the TA lists the preliminary plant conditions previously discussed. The original stimulus is written in the left center of a blank analysis sheet along with its response, and the paradigm is continued out to the right by listing the obvious next set of stimuli associated with the initial response.

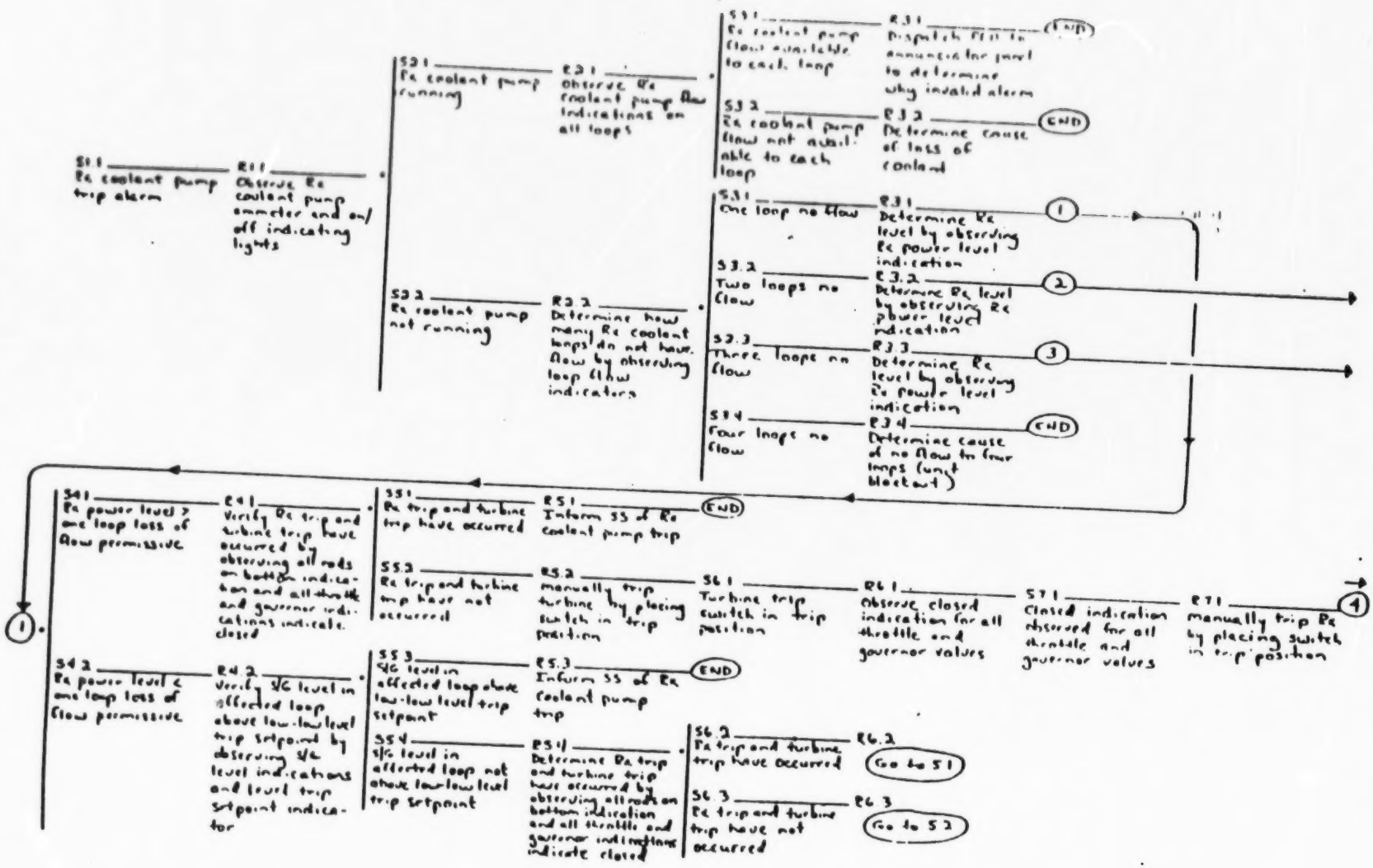
Figures B-4 and B-5 provide examples of completed paradigms of nuclear industry tasks.

There are several procedures and mechanical techniques that are followed:

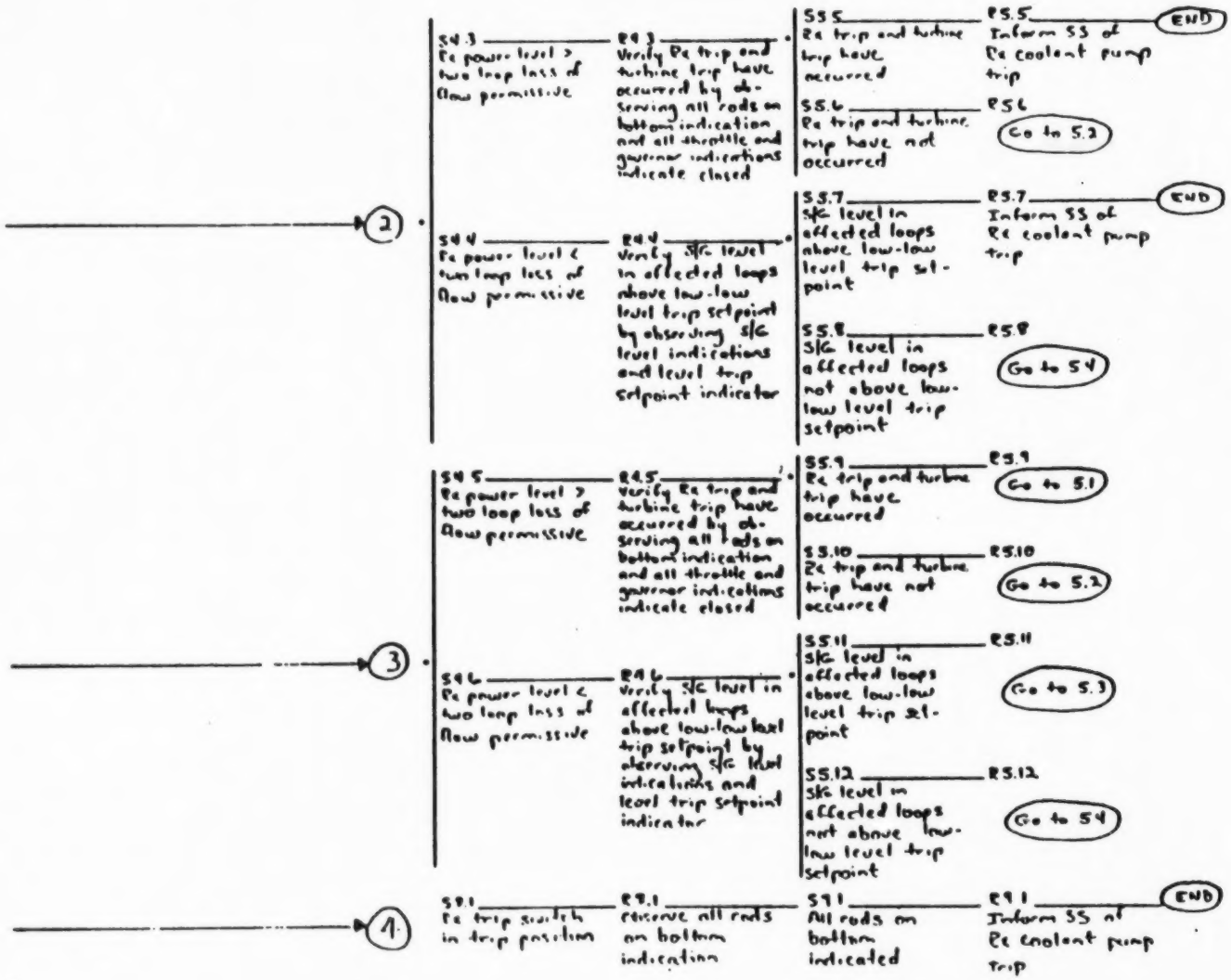
1. Every stimulus must have a response.
2. Paradigms always end with a response.
3. There can be more than one stimulus for a single response.
4. There can be only one response for a stimulus or set of stimuli.
5. There are only three ways to end a paradigm:
   a. The sequence of actions for the operator is completed. Any continued actions are outside his job. Example: Initiate work request to repair pump.
   b. The sequence of actions leads to a task that has been previously analyzed. Example: After a reactor trip, the plant is stabilized; carry out the procedure for a plant shutdown (separate task).
   c. The sequence of actions is completed. Example: Pump trips, operator starts standby pump, system is back to normal, operator reports event and logs completion.
6. All paths must be carried to a conclusion which meets one of the three ends previously mentioned.



Example Paradigm - "Backfeed Unit Auxiliary Transformer from Main Transmission Switchyard (Main Turbine Generator Links Removed)"


S1.1 Rx coolant pump trip alarm
R1.1 Observe Rx coolant pump breaker and on/off indicating lights
S2.1 Rx coolant pump running
R2.1 Observe Rx coolant pump flow indications on all loops
S2.2 Rx coolant pump not running
R2.2 Determine how many Rx coolant loops do not have flow by observing loop flow indicators
S3.1 Rx coolant pump flow available to each loop
R3.1 Dispatch I&C to annunciator panel to determine why invalid alarm
S3.2 Rx coolant pump flow not available to each loop
R3.2 Determine cause of loss of coolant
END
S3.1 One loop no flow
R3.1 Determine Rx level by observing Rx power level indication
1
S3.2 Two loops no flow
R3.2 Determine Rx level by observing Rx power level indication
2
S3.3 Three loops no flow
R3.3 Determine Rx level by observing Rx power level indication
3
S3.4 Four loops no flow
R3.4 Determine cause of no flow in four loops (unit blackout)
END
S4.1 Rx power level ≥ one loop loss of flow permissive
R4.1 Verify Rx trip and turbine trip have occurred by observing all rods on bottom indication and all throttle and governor indications indicate closed
S4.2 Rx power level < one loop loss of flow permissive
R4.2 Verify S/G level in affected loop above low-low level trip setpoint by observing S/G level indications and level trip setpoint indicator
S5.1 Rx trip and turbine trip have occurred
R5.1 Inform SS of Rx coolant pump trip
END
S5.2 Rx trip and turbine trip have not occurred
R5.2 manually trip turbine by placing switch in trip position
S5.3 S/G level in affected loop above low-low level trip setpoint
R5.3 Inform SS of Rx coolant pump trip
END
S5.4 S/G level in affected loop not above low-low level trip setpoint
R5.4 Determine Rx trip and turbine trip have occurred by observing all rods on bottom indication and all throttle and governor indications indicate closed
S6.1 Turbine trip switch in trip position
R6.1 Observe closed indication for all throttle and governor valves
S7.1 Closed indication observed for all throttle and governor valves
R7.1 manually trip Rx by placing switch in trip position
4
S6.2 Rx trip and turbine trip have occurred
R6.2 Go to S1
S6.3 Rx trip and turbine trip have not occurred
R6.3 Go to S2
1

Example Paradigm from PWR Plant Analysis - "Partial Loss of Reactor Coolant Flow" (Page 1 of 2)


S4.3
Rx power level > two loop loss of flow permissive
R4.3
Verify Rx trip and turbine trip have occurred by observing all rods on bottom indication and all throttle and governor indications indicate closed
S5.5
Rx trip and turbine trip have occurred
R5.5
Inform SS of Rx coolant pump trip
END
S5.6
Rx trip and turbine trip have not occurred
R5.6
Go to S.2
2
S4.4
Rx power level < two loop loss of flow permissive
R4.4
Verify S/G level in affected loops above low-low level trip setpoint by observing S/G level indications and level trip setpoint indicator
S5.7
S/G level in affected loops above low-low level trip set-point
R5.7
Inform SS of Rx coolant pump trip
END
S5.8
S/G level in affected loops not above low-low level trip setpoint
R5.8
Go to S4
S4.5
Rx power level > two loop loss of flow permissive
R4.5
Verify Rx trip and turbine trip have occurred by observing all rods on bottom indication and all throttle and governor indications indicate closed
S5.9
Rx trip and turbine trip have occurred
R5.9
Go to S.1
S5.10
Rx trip and turbine trip have not occurred
R5.10
Go to S.2
3
S4.6
Rx power level < two loop loss of flow permissive
R4.6
Verify S/G level in affected loops above low-low level trip setpoint by observing S/G level indications and level trip setpoint indicator
S5.11
S/G level in affected loops above low-low level trip set-point
R5.11
Go to S.3
S5.12
S/G level in affected loops not above low-low level trip setpoint
R5.12
Go to S4
S3.1
Rx trip switch in trip position
R3.1
Observe all rods on bottom indication
S3.1
All rods on bottom indicated
R3.1
Inform SS of Rx coolant pump trip
END
1

Example Paradigm from PWR Plant Analysis - "Partial Loss of Reactor Coolant Flow" (Page 2 of 2)

7. Numbering of the stimuli and responses is a method of identifying their location on the paradigm and is done in generations (see Section B.5.4). This is done after the paradigm is completed. These numbers are used later to transfer to the task analysis sheets and for location.

8. The "go to" is a short-cut method used by the TA to preclude the repetition of a stimulus-response path that has been previously written. A "go to" can only be from a response to a response. A "go to" is a connector from one branch of the pathway to another branch and is annotated by, "R4.2 Go to R3.2". When this is transferred to the task analysis sheet, usually no additional skills and knowledge will be required.